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Biofuel policies and the reforms of the Common Agricultural Policy

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A Monica et Marianne.

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Summary

Biofuels are being extensively developed around the world thanks to the support of states, which is a necessary condition for their production. Thus, the focus of this dissertation is to study the regulation of biofuel policies. More precisely, this work intends to enlighten the strong links between biofuel and agricultural policies. Policies directed to biofuel production have changed dramatically over the past three years, evolving from the status of a secondary policy within agricultural policies to the position of a central policy at the crossroads of agricultural, environmental and energy policies. The work exposed in this dissertation is divided in three parts. First, the reasons that have led to the sudden development of biofuels are presented. Then, in a second part, the interactions of biofuel policies with the present agricultural policies are dealt with. The aim of this second part is to assess the extent to which these policies ought to be amended in order to account for the growing importance of energy crops in the total agricultural production. Finally, the third part focuses on the new regulatory framework imposed by the dual production of the agricultural sector (an environmental good and an agricultural commodity): a Common Agency setting is chosen to address this issue. Moreover, this last part strives to anticipate the future reforms of the CAP, in which the dual regulation (at the EU and Member State levels) calls for a new framework for policy analysis. Hence, the common thread of all the ideas developed in this dissertation is the mutual interactions that exist between biofuel and agricultural policies. Biofuel policies have emerged thanks to the

reform of the CAP in 1992, are now an important player of the present CAP and will undoubtedly be a central issue in the future reforms of agricultural policies.

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Introduction

Biofuel policies have by now gained a significant importance worldwide. While huge biofuel plans have been unveiled, the setting of ambitious production objectives does not close the discussion over biofuels. On the contrary, an intense scientific debate on the links between biofuel policies and agricultural, environmental and energy policies has been building up.

Biofuels are produced from a wide variety of feedstocks, in a growing number of countries. Indeed, the generic term "biofuels" spans a large array of situations. A quick overview will help visualizing the products that will be referred to all along this dissertation. There are two leading biofuels in the world: ethanol and biodiesel, respectively blended with gasoline and diesel. Ethanol is produced from sugar crops (sugarcane or sugarbeet) or crops containing starch (corn, wheat and cassava principally). Biodiesel is made by esterifying a simple alcohol (generally methanol) with a vegetable oil (rapeseed, soybean, palm, sunflower, coconut, coton, etc.). The co-products of biodiesel production are cakes (stemming from the crushing of oilseeds), and glycerine (produced during the esterification process). While cakes can be used to feed cattle, glycerine is directed to the cosmetic and pharmaceutical industries. Contrary to ethanol, biodiesel is not a simple molecule: its properties hinge upon the feedstock used to produce it.[1] Ethanol from sugarcane (produced mainly in Brazil)

[1] The most important physical property is the formation of wax at cold temperatures. For instance, palm oil becomes solid below 15°C, which prevents its exclusive use as a feedstock for biodiesel in temperate climates: it must be blended with soy oil or rapeseed oil.

is characterized by the lowest production costs and the highest energy yields, since a co-product obtained from sugarcane crushing (bagasse) is burnt for power generation in distilleries.

Biofuels depend on two markets for their profitability: the agricultural commodities market, which determines the price of the input, and the oil market, which is the main determinant of the price at which biofuels are traded. However, we should not conclude that the influence of biofuels on both market are of the same magnitude: if the signs of an influence of the biofuel boom on agricultural markets have materialized (see, e.g. Babcock, 2007 and Schmidhuber, 2007), the influence of biofuel production on the oil market is nill, biofuels being still very small players in the energy market. Hence, our studies have been conducted on the premise that the relationships between biofuels and agriculture were a richer field to invest than the links between biofuels and the energy market.

There are many quantitative studies being now conducted on biofuels, be it on a very small scale (a county in the USA where a corn plant has been built) or on a global scale (general equilibrium models predicting the evolutions of prices in response to a demand shock generated by the emergence of biofuels). However, the ever changing scopes of biofuel programs[2] and the uncertainty over the durability of the commitment from the states (as regards economic instruments set up to develop the biofuel sector) call for a very frequent update of the studies, whose results become obsolete within a

[2] The US and the EU have repeatedly increased the objectives of their biofuels plans over the past 5 years. In the US for instance, a plan forescasting 7.5 billion gallons in 2012 was announced in 2005. In 2007, a new biofuel program raised these figures to 35 billion gallons in 2017.

few months. Moreover, these studies often brush under the carpet the fact that the biofuel industry is massively supported by the states. Hence, any study that puts forwards the positive effects of biofuels (as regards agricultural prices for instance) should not forget that huge amounts of money are being spent (by the taxpayer or the consumer) for this industry to break even. These subsidies (and mandatory blending schemes) come in addition to the "traditional" payments directed to agriculture. In the US and in the EU, the support adds up to $4 billion per year (subsidies only). Even in Brazil (the most efficient producer in the world), the support is evaluated at $1 billion (OECD and ITF, 2007). The aim of this thesis is not to assess the profitability of biofuels in 10 years' time for instance. This undertaking would be meaningless: biofuels are positioned in the midst of swiftly changing frameworks. A plumetting oil market and/or strong agricultural prices are the greatest risks that could affect their profitability in the upcoming years. Should such a scenario concretize for biofuels, the support of the states would then be put into question, as the needed tax-cuts for the biofuels to break even could quickly become unsustainable for their budgets (likewise, a biofuel mandate in such a market configuration would be harshly criticized by consumers associations). Moreover, environmental concerns (linked to the sustainability of palm oil production for instance) could be a reason leading to a phasing out of the support awarded to biofuels.

The point of view chosen in this study is a public economics approach, in which we strive to consider the widest range of consequences caused by the decision to produce biofuels. This means that we ought to encompass a large array of economic agents (farmers, consumers, taxpayers, biofuel industries, food industries, national government, federal government, etc.) in our study and to take into consideration the many related policies with which biofuel programs interact (environmental, energy and agricultural policies mainly). The cornerstone of biofuel economics lies in the strong implication of the regulators in the setup and the running of biofuel programs. Indeed, no biofuel program can emerge without the strong will of a regulator to support such a policy, since the production of biofuels is almost never profitable.[3] Hence, a large consensus has simultaneously been building up in many countries under the pressure of well-organized agricultural lobbies. Biofuel programs have obtained huge levels of public support (be it under the form of tax cuts or mandatory blending) which have triggered off high levels of production.[4]

Until the beginning of years 2000, biofuels were largely considered as a mere accompanying measure of agricultural policies in the United States (US) and in the European Union (EU). The case of Brazil was not really different, as the Proalcool program launched in 1974 was mainly a plan established to stem overproduction concerns affecting sugarcane distilleries. More recently, the new plans launched in years 2000 have somehow widened the scope of biofuel policies. Biofuels have thus been presented as policies aiming at alleviating CO_2 emissions concerns in the transportation

[3] Ethanol has been profitable in Brazil in 2005 (ESMAP, 2007), but this should be considered as an exception.

[4] However, as the French situation highlights, the decisions of the regulators to embark on strong biofuel supports have been only remotely influenced by economic reasoning. The French agricultural lobbies have relied extensively on reports made by counsulting firms in order to promote the use of biofuels. These reports ignored the economic concepts such as opportunity cost and thus led to overly positive conclusions.

sector (as in the EU) or improving energy independence (as in the USA).[5] However, the aim of this dissertation is to show that all these alleged objectives for biofuels have been overstated: the main objective of biofuel policies has been the support of agricultural incomes. Indeed, biofuel policies have always had a very tight link with agricultural policies. The backbone of this dissertation is therefore the links between biofuel policies and the reforms of the Common Agricultural Policy: past, present and future. Of course, the objective of this dissertation is not to proceed to an exhaustive presentation of the successive CAP reforms. It is rather to enlighten the CAP features which have a relationship with biofuel production.

The three parts of this thesis aim at underlining the close relationships that have been building up between biofuel and agricultural policies.

Part I focuses on the emergence of biofuel policies. In the EU, biofuels have emerged thanks to a reform of the Common Agricultural Policy in 1992, namely the introduction of the mandatory set-aside to stem overproduction concerns. Hence, biofuels appeared since a feature decided in the 1992-CAP left a set-aside land that could be cultivated with energy crops.[6] The motivations of the states to develop biofuels as well as the economic instruments they resort to are presented in *Chapter 1.* This chapter also provides a comparison of biofuel policies with the agricultural policies of the 1980s. As the development of biofuel programs gained strength over the

[5] However, it should be noted that two recent articles published in *Science* (Searchinger *et al.* and Fargione *et al.*, 2008) show that the carbon balance of biofuels would indeed be negative, owing to a "carbon debt" incurred by biofuels when their production implies land-use changes leading to a carbon release (e.g. primary forest or peatland transformed into crop fields to produce biofuels).

[6] Of course, the implementation of the set-aside was only a small part of the 1992 CAP reform. This reform marked the beginning of a shift from price support to direct support, which culminated with the 2002 Mid Term Reform, further completed by the 2007 "Health Check". For further details, see Bureau, 2007.

past few years, the economic questions surrounding biofuel development have sharply evolved. Biofuels have long been a secondary matter in agricultural economics. In the European Union (EU), their emergence is linked to a reform of the Common Agricultural Policy (CAP), which set aside part of the arable land (around 10%, depending on the year) and thus enabled the production of energy crops on this land where the production of food crops was forbidden (in order to address the problem of overproduction). The economic questions linked to the production of biofuels on set-aside land were well-circumscribed and rather straightforward to answer. The relative easiness in treating the question stemmed from the marginal situation of biofuel production (and by extension, of energy crops production) which set a framework in which biofuels did not have any influence on the economic variables which determined their profitability. Indeed, the energy demand constituted by biofuels was so small relatively to the food demand that it had no effect on the equilibria of world agricultural markets. Of course, biofuels had all the more no influence on the energy markets, as the share of biofuels in the total energy used in the transportation sector are extremely marginal even today (cf. appendix to *Chapter 2*). Hence, the welfare economic studies compared two situations: producing or not producing energy crops on set-aside land. We shall shortly address these questions for France in *Chapter 2*.

Everything changed with the unveiling of massive biofuel programs in the OECD countries, but also in developing countries. The huge increases that have been observed in the agricultural markets since 2005[7] give compelling evidence of a strong

[7] For instance, wheat price in Europe has been multiplied threefold since 2005.

link between biofuel production and the price increase.[8] Part II therefore concentrates on the implications of the large biofuel programs on the actual decoupled CAP policy. Contrary to part I which demonstrated a formal link between a CAP reform and the emergence of biofuels, the present CAP policies seem formally unrelated to biofuel policies. However, the large price impacts of biofuel production on agricultural markets call for a complete re-thinking of the present CAP policy with respect to the payments awarded to farmers (*Chapter 3*) and the environmental provisions (*Chapter 4*). Indeed, with the higher price levels triggered by the additional demand for biofuels, farmers enjoy a double economic support (CAP decoupled payments in addition to the subsidies for biofuel production). This situation looks bound for a profound reform as such a big support awarded to farmers seems difficult to justify in a period of high commodity prices: one solution could be a decrease of decoupled payments, as will be explained in *Chapter 3*. Hence, the emergence of biofuel policies marks a profound change in the path of agricultural policy reform, which has mainly consisted in decoupling the support awarded to farmers from production decisions. This evolution has begun with the 1992 reform and was further reinforced during the Agenda 2000, Mid-term Reform in 2002 and the "Health-Check" which ought to be adopted prior to the end of 2008.

We present a model of competition between food and energy uses of agricultural products to evaluate the effects of a biofuel support policy (mandatory blending or tax-cut). The model brings together the main stakeholders of the policy under

[8] Of course, biofuel production is not the sole factor that explains this price increase. Historically low stocks, harsh weather conditions and a sustained Asian demand contribute to the recent price increase.

scrutiny: taxpayers, farmers, taxpayers, as well as biofuel and agro-food industries. The increase in farm incomes made possible by the price hike in agricultural markets enables the regulator to diminish the decoupled payments, while ensuring a parity income to farmers. These central questions are addressed in *Chapter 3*.

Projected real food crop prices, 100 in 2004.

	2007	**2008**	**2009**	**2010**	**2015**
Real Prices					
Maize	141	179	186	176	155
Wheat	157	219	211	204	157
Rice	132	201	207	213	192
Soybeans	121	156	150	144	127
Soybean oil	138	170	162	153	119
Sugar	135	169	180	190	185

World Bank (2008)

	March 2008	Δ% January 2005
Wheat	440$/ton	186%
Corn	233$/ton	142%
Soybeans	576$/ton	120%
Sugar	291$/ton	51%
Palm oil	1248$/ton	210%

IFAP-WABCG (2008)

As the biofuel programs began to interact with other sectors, the consequences of biofuel production began to appear far-reaching in scope. The changes might be positive or negative, each linkage between biofuels and the policy under scrutiny needing a thorough examination.

Moreover, the framework of higher prices and decreased decoupled payments puts the cross-compliance schemes at risk: a new regulation of environmental provisions of the CAP ought to be designed. The close links that have been building up between biofuels and agriculture were quite easily predictable, once the major biofuels plans in the OECD countries had been announced. Indeed, all the quantitative models pointed to higher agriculture prices in response to the demand shock constituted by biofuels. However, the extent of the downside risks affecting the environment has been gaining momentum as the first effects of the biofuel plans were gauged: the increased use of fertilisers and pesticides in the USA and in the EU, as well as very serious concerns about the sustainability of palm oil plantations in Indonesia and Malaysia. Hence, environmental policies are in the meantime the reason that pressed governments to develop biofuels (touted as the solution to GHG concerns in the transportation sector) and one of the most embarrassing negative aspects that jeopardize the continuation of biofuel policies. The links between biofuel policies and the environmental provisions in agricultural policies will be dealt with in *Chapter 4*, with an emphasis on the enforcement issue. Hence, biofuel policy calls for a profound modification of the present Common Agricultural Policy, which has been enacted recently (decided in 2003 and enforced in 2005).

Finally, part III aims at formalizing agriculture's dilemma between high production levels and the respect of stringent environmental provisions linked to the CAP. Of course, such a tension between environmental and production objectives has always existed. However, the introduction of environmental provisions in the CAP used to take place in a situation of low agricultural prices. With the emergence of biofuels (and the price hikes that they trigger off), the opposition between these two objectives is reinforced.

The last two chapters are built around the framework of Common Agency, a new branch of Contract Theory. This theory extends the Principal-Agent model to the presence of n principals (most often, $n=2$). It[9] appears to be a well-suited theoretical framework to study agriculture's dilemma for producing two types of goods like environmental (effort for reducing the use of polluting inputs) and "classical" agricultural goods. The question of interest is thus to assess the consequences of the competition between the two principals on the allocations levels. Common Agency will be presented in *Chapter 5.*

Chapter 6 strives to model the regulation of the two types of goods produced by agriculture: an environmental good and a "classical" agricultural commodity. More generally, there is a tension between the stringent environmental objectives that the EU entities (most often the Commission) wish to promote and the opposition of the MS willing to unleash the production capacities of their agricultural sector. Hence, *Chapter 6* addresses the issue of regulation in the EU context, i.e. with a competition between the supranational regulator (the EU Commission) and the national regulator (a Member State). More precisely, the regulation which is considered gives the leadership for imposing its environmental regulation to the EU. This regulation framework fits well into the setting up of the Common Agricultural Policy's successive reforms,

[9] The Common Agency adds a very important feature with respect to the traditional principal-agent relationship: the competition between the two principals in their contractual offer. Therefore, when offering her contract to the agent, the principal cannot only consider the agent's strategic behavior in revealing his information to her, she must also take into consideration the way the other principal's contract will affect the agent's information revelation to her.

in which environment has been gaining pre-eminence over time. Moreover this two-regulators, sequential setting paves the way for future reforms of the CAP, in which a possible re-nationalization would still call for a powerful environmental regulation at the EU level.

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Part I Biofuels: the origins of their development

Biofuels have been developed widely for only a few years now and could appear at first sight as an *ad-hoc* solution found by many developed and developing countries to curb their carbon emissions in transports. However, this possible explanation for the outbreak of biofuels is incorrect. This sudden growth has indeed very deep roots in agricultural policies, as will be demonstrated in the case of France in *Chapter 2*. But first, *Chapter 1* will present the policies set up by the states to develop biofuels and the alleged objectives behind these policies. This chapter will show that the expansion of biofuel production rests on the decision by the State to support the biofuel industry, which is not profitable without this support. Moreover, *Chapter 1* draws some parallels between biofuel policies and the former agricultural policies, as far as commodities price support is concerned.

Chapter 1
A strong involvement of the states

An illustrative example: China

We shall begin this chapter dedicated to the involvement of the states in biofuel policy by describing the Chinese biofuel situation. It might seem uncommon to begin a presentation dedicated to biofuels with China, since it is by no means the leading producer in the world (China is the third ethanol producer, far behind Brazil and the US). However, an overlook at the support programs that have been set up in this country may help understand the programs in other countries, and above all, the key role played by the states.

The main feedstock used to produce ethanol in China is corn (other feedstocks such as cassava and sugarcane are used, but only marginally), which represents over 80% of the total ethanol produced in the country, which adds up to 1.2 billion liters in 2005 (Foreign Agricultural Service, 2007). Recent concerns about food security have led China to use imported tapioca (from Thailand) to produce ethanol. Besides, the government has restricted the production of ethanol from corn at the end of 2006. In 2007, a 5-year plan of biofuel production was introduced by the National Development Reform Commission (NDRC) which set very ambitious goals for the sector. However, the State Council decided not to approve the plan because of the recent surge in commodity prices and concerns that ethanol could compete with crops planned for human consumption (Foreign Agricultural Service, 2007). Hence, the original target of 5.22 million tons forecasted for 2010 has been revised downwards to 3-4 million tons, with an increased part of feedstocks from non-arable lands (e.g. tuber crops and sweet sorghum). Moreover, the government eliminated the rebate on the 13% value added tax granted to ethanol, by fear of grain shortages. Besides, additional incentives for biofuels will be provided when world oil prices fall below a threshold level. Considering all these elements, it clearly appears that the Chinese biofuel program will mainly hinge upon discretionary and changing rules edicted by the government rather than the market. This observation looks hardly surprising for a country ruled by a Communist Party, with a pervasive public sector. However, as far as biofuels are concerned, the Chinese situation is by no means an exception: all biofuel policies (even in the low-production-cost-Brazil) are highly dependent on governmental decisions. These decisions are not limited to the mere design of biofuel programs: a permanent involvement of the state is needed throughout the duration of the program to adjust the supports awarded to biofuels in an ever changing economic framework.

1.1 The objectives behind biofuel policies

A very wide array of objectives are put forward by the countries that have decided to develop biofuels. The objective which is most often invoked is greenhouse gases (GHG) mitigation. Other countries also put forward concerns about energy security or independence, as well as the mitigation of local air pollutants. However, few countries explicitely underline the role played by biofuel programs to support agricultural prices (such as China). The last section of this chapter demonstrates the analogies between biofuel production and target price policies, thus confirming the agricultural motivations behind biofuel policies. It would be too long to detail all the objectives behind the biofuel plans set up by a long list of countries. We will therefore focus on the objectives put forward by the EU Commission.

1.1.1 Environment

The EU[10] has been much more active than any other developed country in implementing the constraining provisions of the Kyoto protocol. Even though the overall balance is unevenly distributed across MS, significant reductions in GHG emissions have already been obtained in some European countries, for example in the United Kingdom, thanks to political willingness. In that context, biofuels are presented as a significant instrument of the EU strategy to reduce GHG emissions. Nevertheless, the biofuels contribution to the fight against GHG emissions will undoubtedly remain modest (at least as far as first generation biofuels are concerned). According to the more recent proposals of the European Commission, biofuels could replace 10% of fossil fuels used in the transport sector by 2020. Knowing that the transport sector accounts for "only" 25 to 30% of GHG emissions and that the assessment in terms of GHG emissions of first generation biofuels relative to fossil fuels is limited, the effect of biofuels on the EU GHG emissions will be small, less than 1% of the total EU GHG

[10] This section is an excerpt from an article prepared for a Biofuel Conference in St-Louis, Missouri (April 2007) by Bamière L., Bureau J-C, Guindé L., Guyomard H., Jacquet F. and Tréguer D.

emissions (our estimates). Of course, any contribution, even marginal, to the Kyoto Protocol objectives is welcome. But the costs of the GHG emission reduction induced by an increased use of biofuels should be counted against alternatives offered by the Kyoto Protocol, including the Clean Development Mechanism. In that perspective, until recently, the price of traded carbon emission rights provided a useful benchmark for stakeholders involved in the biofuels industry (as well as for public authorities). The recent collapse of this price, due to a very generous allocation of emission rights, makes the assessment more difficult. This episode is unlikely to increase incentives to boost investment in biofuels.

1.1.2 Energy

The development of biofuels is also motivated by the concern of reducing dependence on EU energy suppliers given the threats of supply cut by Russia and the ongoing uncertainties in the Middle East. Today, the EU depends on imports for half of its energy needs. According to current trends, the dependence should increase in the next years to reach 65 % in 2030 (Fischer Boel, 2007). However, according to the EC analysis, the EU biofuels policy if fully implemented and respected might help saving only 3 % of imported fossil oil (COM(2006) 34). Even if this marginal contribution will be welcome, it cannot alone justify the EU biofuels strategy, notably tax exemptions or reductions. Importing (very) large amounts of biofuels would allow the EU to diversify energy sources and reduce dependence on a handful of suppliers, but not to gain more self-sufficiency in terms of energy needs.

1.1.3 The CAP

Behind the Commission's policy promoting biofuels, and perhaps behind that of some MS, is the objective of providing larger outlets and employment to the farm in a context where exports subsidies have been significantly cut, foreign market access has been substantially reduced, and considerable adjustments have been asked to European farmers during 15 years of almost permanent reform. The farm sector represents only a few points of the EU-27 Gross Domestic Product (GDP), roughly 3 %. However, it remains a major economic sector in some countries, not only in the new MS (the percentage of population employed in the farm sector is 30 % in Romania and 16 % in Poland) but also in some MS from the South of the EU-15 (more than 10 % of the population is employed in the farm sector in Greece and Portugal). Even in Northern Europe where the share of population in farming is only a few percentage points, the sector still occupies a large part of land. In several regions, the first transformation food industry which is closely linked to agricultural activity represents a large share of the whole industrial activity (Schmitt et al., 2002). Analyses at a regional level of domestic reform and trade liberalization scenarios suggest that these regions are the areas where the negative impacts would be the highest and the economic prospects the less favorable (Jean and Laborde, 2007). In addition, the future leaves little hope for an ambitious CAP. Income support in the form of decoupled payments will very likely be reduced.[11] At best, they will be reoriented towards environmental and territorial objectives within a constant budget. More probably, there

[11] We shall discuss the likely implications of this policy shift, in conjunction with biofuel production in Chapter 3.

will be a significant reduction in the total agricultural envelope for reassignment on other EU priorities after 2013, if not before. Lastly, the multilateral agricultural negotiations of the Doha Round should result in an increased access to the EU market for foreign competitors. This larger openness of the EU agricultural market should more particularly affect the cattle-rearing areas and the livestock products, but also some cereals (barley and corn) as well as sugar beets. All these evolutions should result in reductions in the European agricultural production. In that context, biofuels are seen as offering more favorable economic prospects to EU farmers. Incidentally, biofuels would also make future adjustments of the CAP, agricultural budget cuts and/or an agricultural agreement within the World Trade Organization (WTO) more acceptable by EU farmers. However, such a reorientation of the CAP would jeopardize the environmental provisions set up during the successive reforms of the CAP. This problem will be addressed in *Chapter 4*.

1.2 The economic instruments used by the states

The economic assessments of the European biofuel programs are largely uncertain, depending on the world markets of energy and agricultural commodities. Uncertainty regarding price elasticities and cross effects with other markets, including the energy market and the demand for similar agricultural products for food use add to the uncertainties on the technical aspects. Economic assessment requires to take into account many interactions, some of them complex, like the role of oil price which affects the competitiveness of biofuels with fossil fuels in both ways, and the feedback between biofuel production, food prices and therefore competition between food and non food use of agricultural products, which affects the production costs of biofuels. No model has yet managed to provide a global analysis that takes into account these interactions in a detailed way, at least as far as EU biofuels are concerned.

Up to now, the production of biofuels only covers a very small amount of the demand for transportation fuel. However, one cannot rely on analyses at the margin or on the extrapolation of past trends. If the production grows significantly, the outlet of some of the co-products will become more limited. This means that the break-even point of biofuels, compared to fossil fuel, will increase. The farm prices will go up, which would drive biofuels further away from being competitive with fossil fuels. It thus creates the risk of artificially supporting investments which will not find competitive raw material any longer (Schmidhuber, 2007).

It should be stressed that in the EU, compared to the North American biofuels, a greater part of the cost is represented by the raw material. Indeed, the oilseeds account for nearly 80% of the manufacturing costs for biodiesel, whereas corn only represents half of the US ethanol costs. Changes in the CAP could thus modify the overall current economic assessment. Lastly, technical change in the biofuel production process itself should not be underestimated. However, at the present time, EU biofuels fall short of being profitable without government intervention. The present growth in production largely results from the combination of the mandatory targets, tax exemptions and CAP subsidies (the combination of instruments used being very variable depending on the MS).

There are 3 main economic instruments used by the states to develop biofuels: tax-reduction on fuels, mandatory blending and import tariffs.

1.2.1 Reduction of the excise tax on fuels

Fuel tax reduction has been the main economic instrument used to promote biofuels (even Brazil still resorts to this instrument). Of course, this instrument can only be used to the extent that excise tax are levied on fossil fuels. This is the case for developed countries, but in some developing countries, fuels face only low taxes or are even subsidized. Biofuels have historically required high levels of tax reduction.[12] In most cases, fuel tax reductions are granted to domestic and imported biofuels alike, so as to respect WTO rules. However, high tariffs are generally applied to imported ethanol, in order to direct the benefits of fuel tax reductions to domestic producers only. The case of the USA is enlightening: a tax reduction of $0.51 per gallon ($0.13 per liter) is awarded for blending ethanol, however, a tariff of $0.54 per gallon ($0.14 per liter) is levied on imported ethanol, thus offsetting the tax reduction benefit.[13]

[12] In the EU, tax reductions for ethanol have been as high as €0.84/l, while in the US, the federal tax credit of $0.135 is often supplemented by the additional tax reductions given out by the states. As for biodiesel, the figures are also quite high: up to €0.60/l in the EU and $0.26 in the US.

[13] Here is a brief chronology of the support directed to ethanol in the US. The first governmental program to support ethanol in the US was initiated by the Energy Tax Act of 1978. A federal tax exemption of $0.40 per gallon ($0.11 per liter) was granted to ethanol. This tax exemption then rose to $0.60 per gallon ($0.159 per liter) in the Tax Reform Act of 1984 before gradually falling to $0.51 per gallon ($0.135 per liter) in 2005. The support granted to ethanol has been extended until the end of 2010. The quantities forecasted by the government plans have been increased significantly over the past few years: in 2005, the Energy Policy Act required a minimum production of 7.5 billion gallons (28 billion liters) by 2012, but as soon as 2007, the quantities were revised upwards to 35 billion gallons (132 billion liters) of ethanol equivalent by 2017 (ESMAP, 2007).

Tax-cuts for biofuels can equivalently be considered as a subsidy. The regulator gives out subsidies to make up for the gap between the production cost of biofuels and the price of the fossil fuel they replace, as the latter is smaller than the former.[14] The cost for society of a tax-cut program in favor of biofuels is greater than the mere budgetary amount spent. We must add up the opportunity cost of public funds, arising from the distortions caused in the economy by levying tax in order to finance public expenses (this issue will be dealt with in *Chapter 3*). The risk exposure in case of a sudden variation in the price of commodities that determine these subsidies (i.e. the price of agricultural commodities and the oil price) is taken on by the State. As the financing of biofuel programs is guaranteed by the State, the variations of prices are dampened by a risk-neutral agent. Moreover, the blending of biofuels does not cause a price increase for the consumer at the gas pump, since the supplementary cost is already accounted for in the tax-cut.

The problems linked to subsidies are inherent to any policy which supports a sector: changes in the support levels cannot be operated as quickly as the sometimes very brutal changes in the markets which determine them. Thus, if the price of oil increases rapidly, it seems hardly possible that the subsidies could be quickly downsized. Conversely, if the price of oil slumps suddenly, the risk of a disruption of biofuel production cannot be completely discarded. A well-known example of such a disruption is given by the first Brazilian ethanol program. At the end of the eighties, the conjunction of the counter oil shock and a very high sugar market sparked off

[14] Biofuels have a smaller energy content than the fossil fuels they substitute for. Hence, the economic value of biofuels corresponds to the price of fossil fuels adjusted for the difference in energy content.

supply problems for cars running solely on ethanol (Elobeid *et al.*, 2006). The agro-industries preferred to sell their sugar cane production to the sugar market rather than to the domestic ethanol production. This example illustrates the intrinsic weakness of biofuel markets, squeezed between energy and agricultural commodity markets.

1.2.2 Mandates

One of the most commonly used instruments to promote biofuels nowadays is mandatory blending. This solution has the advantage of not creating distortions linked to taxation. Besides, it might provide an incentive for consumers to decrease their gasoline consumption, since the blending of a more expensive product (biofuels) with respect to fossil fuels would trigger a price increase at the gas pump. However, this price hike should not be confused with an environmental tax, since the price increase would have no direct relationship with the social cost of an environmental externality. In case of a brutal price hike in agricultural commodity markets, the additional cost that will ensue would be borne by individuals on their own, each characterized by risk aversion.

1.2.3 Tariffs

As noted earlier, states tend to couple tax reductions on biofuels with import tariffs in order to grant the benefits of their policy to domestic producers only. The situation is quite contrasted between the two types of biofuels: ethanol is characterized by higher tariffs than biodiesel. The EU applies for instance a specific import duty of

€0.192/l for undenatured ethanol and €0.102/l for denatured ethanol (i.e. mixed with gasoline). However, it seems worth stressing that 101 developing countries enjoy duty-free access to the EU ethanol market (under the ACP agreements, GSP+, Everything But Arms...). Brazilian ethanol enters the EU with the Most Favored Nation duty (i.e. €0.192/l or €0.102/l). For its part, the US levies a specific tariff on ethanol of \$0.143/l (plus a small *ad valorem* duty) and also grants a duty-free access to ethanol coming from the Caribbean countries. More surprisingly, even Brazil resorts to import tariffs to protect its domestic producers (it levies a 20% *ad valorem* duty, ESMAP, 2007).

As regards biodiesel, the tariff rates are generally low in industrial countries (6.5% *ad valorem* duty in the EU and 1.9% in the US). Global trade for biodiesel will most likely be prevented by technical barriers such as fuel certification, in response to environmental concerns raised by the clearing of rain forests to produce the feedstocks (soybeans in Latin America and palm oil in Southeast Asia).

1.2.4 Other types of supports

There is a wide range of other supports that have been set up to develop biofuels, e.g. accelerated depreciation, loans, loan guarantees, subsidies for buying flex-fuel cars, etc.[15] In the US, a wide range of states' initiatives supplement the federal schemes to support biofuel production. Thus, some states have passed into law mandates for biofuels: Minnesota is the leading state in that respect since it has mandated a 10%

[15] For more details, see Koplow (2006).

percent blend of ethanol in gasoline since 1997 and further increased the target to 20% by 2013. Other states such as Iowa, Hawaii or Louisiana similarly impose ethanol mandates.

1.3 The EU biofuel program and its implementations by the Member States.

In 2003,[16] the European Union (EU) launched an ambitious policy aiming at increasing the use of biofuels in land transport "with a view to contributing to objectives such as meeting climate change commitments, environmentally friendly security of supply and promoting renewable energy sources" (Commission of the European Communities, 2003). The target for 2010 is that biofuels represent 5.75% of the market for gasoline and diesel in transport.

The development of biofuels in the EU has largely been driven by incentives set up by public authorities in both the agricultural and energy sectors. Without the present set of subsidies, tax reductions and exemptions as well as mandatory incorporation rates, the EU production would certainly be much more limited. The CAP provides incentives for producing biofuels (more precisely for producing energy crops). On the demand side, measures essentially aim at increasing the use of biofuels in land transport. However, because of high tariffs on imports of some biofuels and/or some

[16] This section is an excerpt from an article prepared for a Biofuel Conference in St-Louis, Missouri (April 2007) by Bamière L., Bureau J-C, Guindé L., Guyomard H., Jacquet F. and Tréguer D.

raw agricultural materials used for producing biofuels, these consumption-oriented measures also encourage production.

Measures developed at the farm sector level are part of the CAP. They are thus common to all Member States (MS). This is also the case for external tariffs. By contrast, most of the incentives for using biofuels are the responsibility of MS. The EU sets the objectives, mainly an incorporation rate target, but it leaves national governments free to take "appropriate measures" to meet these objectives. These measures are funded on national budgets. It explains why incentives to production and utilization of biofuels differ a lot across the EU-27 MS. This is particularly the case as far as tax exemptions / reductions are concerned. This is also the case for the relative incentives for producing ethanol or biodiesel: the EU legislation only sets the aggregate objectives, the balance between ethanol and biodiesel is chosen by the MS.

The various European countries will not be subject to penalties if they do not meet the 5.75% incorporation target in 2010. They however will have to provide justifications in case of non-compliance. More precisely, they will have to report the measures undertaken to achieve compliance. Today, the EC explicitly recognizes that the 2003 biofuels use Directive target for 2010 will very likely not be achieved. Rather, the EC expects an incorporation rate of 4% only (Commission of the European Communities, 2007).

The large increase in biofuel production in the EU can largely be explained by the political will, which has resulted in either a large degree of subsidization (through tax exemptions). While the development of both the consumption and the production of biofuels has been impressive in relative growth, the overall use hardly exceeded 1% of transportation fuels in 2005, while it already had a significant impact on markets, driving up the price of rapeseed oil, for example. Even with such limited use of biofuels, the costs for MS budgets have become significant, so that several countries are moving towards less tax exemptions and more constraining targets for mandatory incorporation of biofuels. However, such a policy ends up passing significant costs to final consumers, who have already expressed their discontent (UFC, 2007).

If the use of biofuel grows and reaches the EU target of 5.75% in 2010, and the possible new target of 10% in 2020, clearly the cost of the public support will become more apparent. One may consider that, for much larger quantities of biofuels used in the EU, there is a need to keep public support consistent with major market forces, or at least with the valuation of the actual positive externalities. More practically, either biofuels will have to compete with fossil fuels in terms of cost (either by reducing the production costs of biofuels or because oil prices will be higher). Or the subsidies should be in line with what can be considered as a reasonable price of the GHG emission avoided. This raises several questions: the first one is the extent of the actual positive externalities as far as GHG emissions are concerned. The second one is the actual degree of competitiveness of the EU biofuels, compared to fossil fuels and biofuels produced in other countries. All these elements play a crucial role in the cost-benefit analysis of the EU program.

To sum up, European public authorities and private investors are now at a difficult crossroad for making choices regarding the production of biofuels in the EU.

All the uncertainties raised above make it problematic to assess what the future of the EU biofuels industry could be. In that respect, it is symptomatic to observe that the European public opinion is increasingly critical as regards the development of biofuels in the EU and that a growing number of organizations are expressing their opposition to the incorporation targets presently discussed for 2020 (a 10% market share).

France has set a biofuels incorporation target of 7% in 2010. In order to achieve this ambitious target (more ambitious than the EU recommendation), the French government has combined fiscal incentives with penalties for not complying. The first instrument is a tax reduction of the domestic tax applied on fossil fuels used in land transport (in French, Taxe Intérieure sur les Produits Pétroliers or TIPP). Tax cuts are granted for specific quantities, auctioned to companies at the EU wide level. They can be revised annually according to price levels of petroleum products on the one hand, agricultural raw materials on the other hand. In addition, wholesalers selling petroleum products are subject to another tax: the General Tax on Polluting Activities (In French, Taxe Générale sur les Activités Polluantes or TGAP). They can avoid paying this second tax by incorporating a certain percentage of biofuels. Tax rates increase over time in line with the increase in the incorporation target up to 7% in 2010. These measures result in a high penalty for a seller of transportation fuel that would not include any biofuel, therefore providing a strong incentive to do so and pass through the extra cost to the final consumer. This has recently turned the main French consumers' organization against the whole biofuels policy (UFC, 2007).

Box 1: The economic instruments to develop biofuels in France

Sweden is one of the MS which promotes the most the use of biofuels (essentially under the form of ethanol). This emphasis on biofuels use rather than production suggests that motivations of the Swedish government are more connected to environmental concerns than to farm support. This contrasts with France which strongly opposes importing larger quantities of biofuels or raw agricultural materials that could be used for producing biofuels. In other words, efforts on the biofuels dossier are in France for a large part, if not essentially, motivated by the farm support objective. Sweden has imported ethanol tax free from Brazil using some loopholes in EU tariffs linked to ambiguities in alcohol denomination and classification. This was ended in the beginning of 2006 following pressures from EU agricultural producers. The incorporation target for 2010 is 5.75% but the interim indicative target for 2005 (3%) was higher than the EC recommendation (2%). Since April 2006, the largest gas pump must supply either ethanol of biogas. The obligation will be extended to medium gas stations in 2009. In addition, some imported biofuels, that is the ones subject to high tariffs, are exempted from domestic taxes on fuels. Flex-fuel cars are also exempted from specific fees, for example urban taxes in Stockholm.

Box 2: The Swedish biofuel program

Germany is the sole country which met the 2005 target (2%) with a biofuels market share of 3.8%. This is the result of an ambitious tax exemption plan initially implemented without quantitative limits. However, from August 2006, the German government went back to a limited exemption tax (tax of €0.15 per liter of biodiesel if mixed with diesel and €0.1 if used pure). Ethanol is so far exempted from excise duty (63€/hl). Germany has decided to implement a mandatory incorporation of 6.75% in transport fuel by 2010.

Box 3: The German biofuel program

Since January 2007, the Netherlands have established a mandatory incorporation target for biofuels of 2%. This target is bound to reach 5.75% in 2010. 2007 is the first year where tax exemptions kick in. However, the Dutch government wishes to implement an environmental certification before promoting further the use of biofuels because of concerns raised by various organizations as regards the negative consequences of biofuels expansion in developing countries (deforestation).

Box 4: The biofuel situation in the Netherlands

The United Kingdom (UK) is now giving the priority to mandatory blending under the Renewable Transport Fuel Obligation (RTFO). If retailers of petroleum products do not include a given rate of biofuels in transport fuels, they will have to pay a penalty (buy-out price) of 0.15£/l (i.e., roughly 0.23€/l). Tax exemptions will be maintained until 2010/11: together with the buy-out price mechanism, they will provide a level of support of 0.35£/l (0.52€/l). From 2010/11, tax exemptions will be removed and replaced by mandatory incorporation for a slightly lower level of support (0.30£/l, i.e., 0.45€/l). The UK points out that the EU incorporation target of 5.75% in 2010 will be excessively costly if achieved through subsidies and tax exemptions / reductions. Unsurprisingly and unlike many other European countries, the UK is vigilant to comply with the spirit of the 2003 Directives on biofuels stating that there should not be overcompensation for the costs of using biofuels. The UK has officially announced that it will very likely not achieve the 2010 incorporation target of 5.75%. Simultaneously, it has also announced supplementary measures to increase incorporation of biofuels (accelerated depreciation rules for biofuels plants and support to distribution infrastructures of ethanol mixed gasoline).

Box 5: The biofuel program in the United Kingdom

1.4 Welfare implications of biofuel production

This section[17] intends to show that biofuel policies are primarily designed for agricultural income objectives. After describing the features of the agricultural policies

[17] This section is based on an ongoing work with J.-C. Bureau and A. Gohin. All errors or omissions are mine.

from the 1980s, we detail the welfare impacts from a domestic production of ethanol (respectively from corn in the US and from wheat in the EU). We thereafter compare the welfare implications of this new biofuel policy with the instruments used in the former agricultural policies (target price and deficiency payments for the USA and export subsidies for the EU). Moreover, we show that the countries which engage in biofuel policies may gain with respect to the former agricultural policies, while the rest of the world unambiguously lose. Note that we only focus on the consequences of biofuel production on agricultural markets (i.e. the supplementary demand to agriculture). Hence, the environmental externalities linked to the production and the use of biofuels in cars are not addressed in this section.

1.4.1 The agricultural policies of the 1980s

In the EU, a major characteristic of agricultural policy support in the 1980s was the organization of transfers from consumers to producers, through (high) guaranteed prices. Most major agricultural sectors were subject to intervention prices, together with a system of import duties, public intervention purchases to support prices above a pre-defined target price, and export subsidies to dispose the excess production that was not purchased by consumers. Markets were also largely administered in the US, where market management dated back to the 1930s. A system of "loan rates" acted as a floor price for producers. Unlike the EU, the taxpayer was asked to contribute to a larger share of the support, since the deficiency payments that covered the difference between this loan rate and target prices (see Gardner, 1992, Helmberger 1995 for clear explanations of these policies and welfare effects).

The shortcomings of the system became apparent in the 1970s and unbearable in the 1980s. EU consumer support peaked with the growing discrepancies between EU institutional prices and world market prices, depressed by EU export refunds and the successive export enhancement programs that the US implemented in order to retaliate. Intervention stocks and export refunds generated considerable budget costs. This has led the EU to solve the problems of imbalance between supply and demand by a series of reforms that have ranged between 1992 and 2006. A common feature of these reforms that have affected most common market organization is a reduction of the role of market price support. In particular, the intervention (i.e. guaranteed) prices for wheat have been halved in current prices between 1992 and 2005. There is no longer any intervention prices for commodities such as corn, rye, rice, beef and sugar (even though a safety net still exists in the last two cases). Farmers have been compensated for these cuts in administrative prices through a system of direct payments. Progressively, these payments have had less linked with the quantities produced. Since the 2003 reform (i.e. in practice since 2006 in most Member states), most of these payments have been decoupled from production, i.e. granted on an historical basis, and would be provided even in the absence of production. Direct payments are now the main component of the EU agricultural support provided to farmers, even though this total support is notoriously difficult to measure.[18]

[18] Both the measures used by the World Trade Organization (the Aggregate Measure of Support) and the ones used by the Organisation for Economic Co-operation and Development (the Producer Subsidy

In the US, the shift of support from consumers to taxpayers is less obvious, given that for a long time the gap between the price guaranteed to producer and the world prices were largely paid by taxpayers, but also because policy reforms have been less dramatic than in the EU. While the EU has followed a consistent path of reforms towards supporting farmers with lump sum payments, the US has followed a more erratic path. However, the share of support that is no longer tied to production or actual prices has also increased between 1987 and 2000.

1.4.2 Welfare variations triggered by biofuel policies

This paragraph intends to detail the welfare consequences of the massive corn ethanol production in the USA[19] (or wheat for ethanol in the EU). In a first approximation, we do not consider the actual consumption of ethanol in the transport sector. In order to understand the dynamics at stake, a thorough analysis from the consequences of biofuel policy on US corn exports[20] (and EU wheat exports) seems necessary. For this purpose, consider the supply (S) and demand (D) of corn in the US, as depicted in figure (1.1). Let (ES_1) be the excess supply from the USA, obtained by horizontally substracting the quantity demanded from the quantity supplied: $ES_1(p) = S(p) - D(p)$. Let also (ED) be the excess demand from the rest of the world. The equilibrium quantity on the world market is $Q_2 - Q_1$, at price P_{w1}, i.e. the quantity supplied by

Estimates and the Total Transfer Estimates) are subject to technical and methodological difficulties.

[19] As the USA is the world's first corn exporter, the impacts of this new corn framework are bound to be sizeable.

[20] The welfare analysis is conducted making reference to the US framework. However, the analysis is exactly the same for the EU wheat ethanol framework.

the American corn producers (Q_2) exceeds the quantity demanded by the American corn consumers (Q_1). Assume now that a quantity Q_B of corn is diverted from the traditional food/feed outlet in order to be transformed into ethanol. We have $D'(p) = D(p) + Q_B$ and the new excess supply on the world market is (ES_2), defined by $ES_2(p) = S(p) - D'(p) = S(p) - D(p) - Q_B$. The new equilibrium quantity on the world market is given by the intersection of (ED) with (ES_2), i.e. $Q_4 - Q_3$, which is traded at price P_{w2}, with $P_{w2} > P_{w1}$. On the domestic market, an aggregate quantity of Q_3 is demanded for corn, of which $Q_f = Q_3 - Q_B$ for food/feed uses, while a quantity Q_4 is supplied by the American corn producers.

Studying the welfare variations from the policy shift in favor of ethanol production, we observe that:[21]

- On the domestic market:
  - corn producers gain area $a + b + c + d$.
  - corn consumers lose area $a + b$.
  - taxpayers lose $Q_B(P_{w2} - \overline{P_E})$, which is the amount corresponding to the subsidy given out to ethanol in order to make it competitive with respect to fossil gasoline ($\overline{P_E}$ is the break-even price for corn directed to ethanol production).
- On the world market, rest of the world's consumers and producers lose area $e + f + g$.

[21] cf figure 1.1

The conclusion of this preliminary analysis is that the rest of the world unambiguously lose from this policy shift, while the US (resp. the EU) may gain from this policy shift if $c + d > Q_B(P_{w2} - \overline{P_E})$.

1.4.3 Comparison between the corn ethanol policy and the target price policy

The target price policy is depicted in figure (1.2), which represents the agriculture supply (S) of corn, the domestic demand (D) and the total demand (TD), made up of the domestic demand (D) in addition to rest of the world's excess demand. The government introduces a target price p_d for farmers which is coupled with a subsidy to enable farmers to sell quantity q_3 at price p_{w1}. For farmers to receive p_d at quantity q_3, the taxpayer has to pay a subsidy $p_d - p_{w1}$ on each unit of output. The target price policy at price p_d has the following welfare consequences with respect to the free trade situation:

- - producers gain area $a + b + c$
  - consumers gain area e
  - taxpayers lose area $a + b + c + d + e + f + g + h$

Overall, for the US, the welfare variation adds up to a loss of area $d + f + g + h$, while the rest of the world gains area $f + g + h$.

Comparing the welfare consequences of the corn ethanol policy with respect to the former target price policy, it appears that:

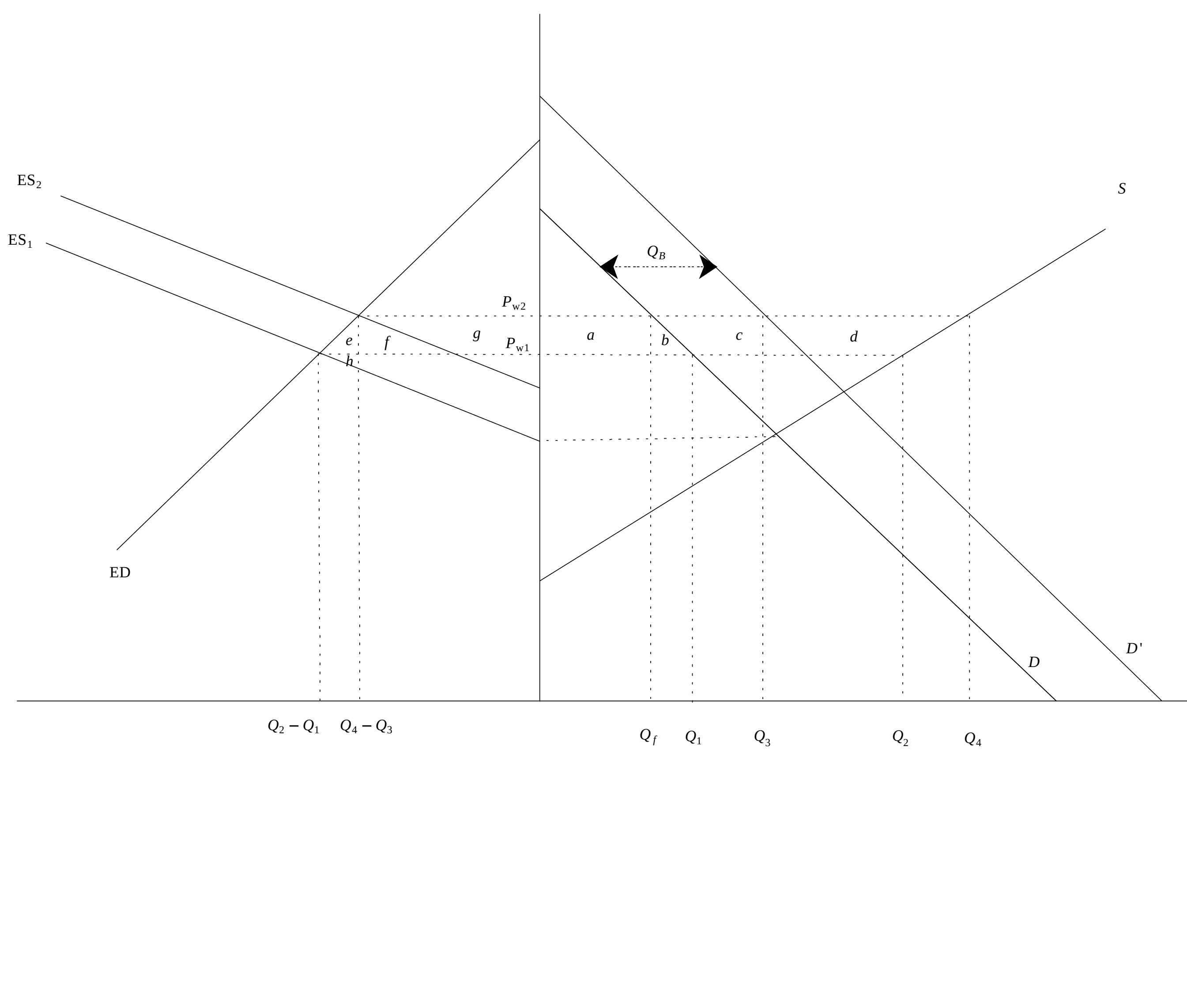

Fig. 1.1. The welfare consequences of biofuel production in the USA or in the EU.

- US producers are indifferent (if the production of ethanol leads to the same price as the target price, i.e. if $P_{w2} = p_d$).
- US consumers unambiguously lose from this policy shift.
- US taxpayers might gain if the amount of subsidy for producing a quantity Q_B of corn ethanol is smaller than the amount paid with the target price policy, i.e. if $(P_{w2} - \overline{P_E})Q_B < (p_d - p_{w1})q_3$.
- Rest of the world's producers and consumers lose on aggregate.

1.4.4 Comparison between the wheat ethanol policy and export subsidies policy

As exposed in Just, Hueth and Schmitz (2004), the EU spent millions of dollars during the late 1980s and the early 1990s to expand international markets under the Export Restitution Program. As the EU had decided to offer a guaranteed price to its farmers well above the world price, it was therefore necessary to get rid of the excess supply on the world market, which was only possible with export subsidies. Figure (1.3) below exposes the welfare consequences from these export subsidies in the case of wheat for instance. EU's supply (S) and demand (D) are represented on the right side, while rest of the world's excess demand (ED) is represented backwards on the left side. In the situation of free trade, $\widetilde{p}_{w2}$ is the domestic and world price, domestic consumption is $\widetilde{q}_1$, while domestic production is $\widetilde{q}_2$. With the introduction of an export subsidy E, the domestic price is increased to $\widetilde{p}_d$, however, the increase in exports triggers a fall

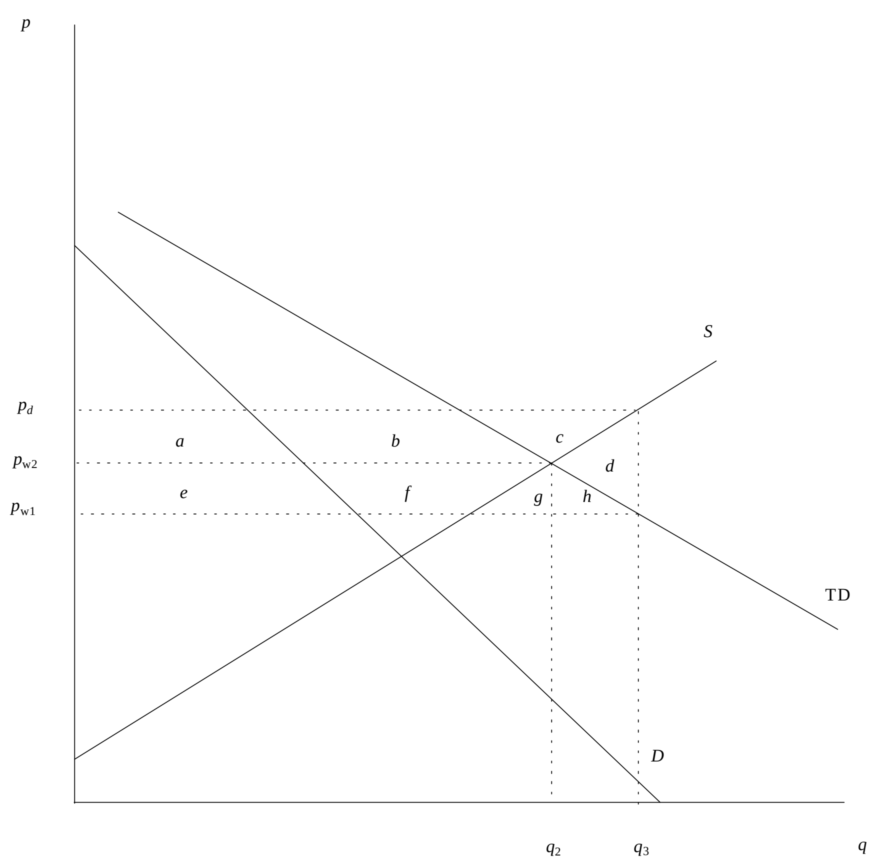

Fig. 1.2. Welfare analysis with a target price and deficiency payments.

in the world price to $\widetilde{p}_{w1}$. Consequently, domestic consumers lose area $a+b$, domestic producers gain area $a+b+c$ and taxpayers lose area $b+c+d+e+f+g+h$ in financing the export subsidy. Hence, the net cost for the exporting country is a loss of area $b+d+e+f+g+h$: export subsidies appear as a very costly way of financing domestic producers. However, note that the rest of the world's producers and consumers gain area $i+j+k$ from the setting of an export subsidies policy.

From the comparison of the export subsidies scheme with respect to the new wheat ethanol policy, we can observe that:[22]

- Consumers and producers are indifferent (if the production of wheat for ethanol leads to the same domestic price, i.e. if $P_{w2} = \widetilde{p}_d$).
- EU taxpayers might gain if the amount of subsidy for producing a quantity Q_B of wheat ethanol is smaller than the amount to finance export subsidies, i.e. if $(P_{w2} - \overline{P_E})Q_B < (\widetilde{p}_d - \widetilde{p}_{w1})(\widetilde{q}_4 - \widetilde{q}_3)$.
- Rest of the world's producers and consumers lose on aggregate.

Hence, we may note that biofuel policies are first and foremost policies designed in order to support incomes in the agricultural sector. Moreover, it might be possible that these biofuel policies prove more efficient in pursuing this agricultural income objective than the previous agricultural policies. This issue will be thoroughly addressed in *Chapter 3.*

[22] Note that figure (1.1) depicts the corn ethanol situation in the US as well as the wheat ethanol situation in the EU.

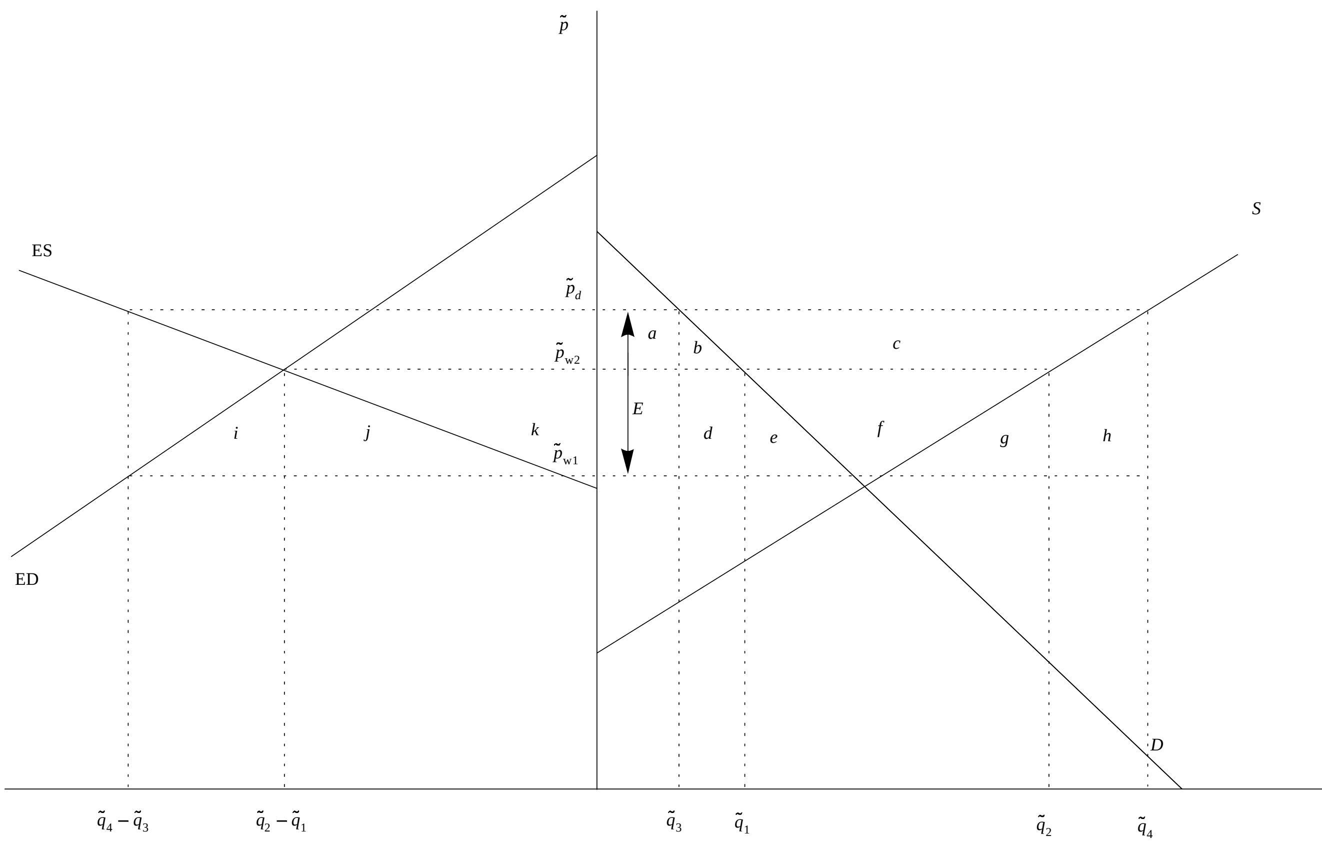

Fig. 1.3. Welfare consequences of export subsidies for a large exporter

Conclusion

To conclude this chapter, it seems worth stressing that biofuel policies are first and foremost policies set up in order to increase the agricultural income and therefore, very close links have been built between biofuel and agricultural policies. It should also be noted that the intervention of the State is a necessary condition for biofuel production to take place. Even if the occurrence of a period of profitability without subsidies for biofuels is not impossible, such events are very uncommon and biofuels do need subsidies from the State (or mandatory blending schemes) in order to be produced (ESMAP 2007).

Moreover, this chapter has striven to underline the close similarities between the previous agricultural policies which consisted in setting a price above the world market price in order to support the agricultural sector. With biofuel production, the economic instrument is no longer a price but a quantity of energy crops that is being produced by the agricultural sector and subsequently removed from the food market in order to be processed into biofuels. The results in terms of welfare might bear some similarities with the previous agricultural policies.

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Chapter 2
The beginning of biofuel production: the land set-aside policy

Preamble

Biofuel production has soared over the past 3 years. The economic analysis that was conducted just after the launch of the main biofuel programs was centered on the production of energy crops on set-aside land, with a look at the competition that was bound to occur between food and energy crops, in response to a biofuel production that would require more land than what the set-aside land could offer. Today, such an analysis may look outdated at first sight. However, the economic study that was conducted back then seems to be a necessary preliminary approach in order to understand the many new economic questions that crop up with the competition between food and energy uses, developed in *Chapter 3*. The present Chapter is an article written by Sourie, Tréguer and Rozakis in mid-2005. Its original title in French was *"L'ambivalence des filières de biocarburants en France"*.

The aim of this chapter is to stress the fact that biofuel production has deep roots in agricultural policies, namely biofuel production has been possible in the EU since a part of the arable land had been set aside for overproduction concerns.

Indeed, biofuel production has only recently been touted as the solution for GHG emissions in the transport sector. During the first years of their production in the EU, biofuels were only presented as a means to increase farmers incomes by giving them the opportunity to produce on set-aside land. Therefore, the scope of biofuel policies was restricted to the field of agriculture production.

Introduction

From a situation of little importance in French crops (324,000 hectares in 2004 including 300,000 hectares of rapeseed), the surface area of energy crops should quickly expand in order to increase the level of incorporation of biofuels in fossil fuels to 5.75% by 2010 (recommended value of Directive 2003/30/EC, "promotion of biofuels"). The French government recently increased the authorized quantities of biofuel production. In the present context where oil prices are close to $70 a barrel and where the fight against global warming has become a priority, biofuels are shown in quite a favorable light. However, considering their very poor energy yield per hectare of land and their high costs, we are led to temper the very optimistic analyses carried out on them. Essentially presented as energy chains, it should not be forgotten that biofuels are also an indirect way of supporting agribusiness and agriculture, under the responsibility of each country.

The main results summarized here concern France. They are obtained by using a sequential partial equilibrium model, OSCAR (Optimisation of the Economic Surplus of Renewable Agricultural Biofuels), developed by INRA (see *Box 6* below for more details on the assumptions used in the model). The strong points of this model consist in a detailed formalization of food and non-food agricultural supplies, considering CAP evolutions and the impacts of biofuels on farm incomes as well as on farm jobs.

2.1 Biofuels, a brief summary

An overview of biofuels shows the prevalence of a continent (America) and of a type of biofuel (ethanol). The latter is made from sugar cane (Brazil) or from corn (USA). Palm oil could very rapidly make its mark on the biofuel market.

The European landscape differs in the choice of its biofuels and energy crops. For the choice of appropriate energy crops, these distinctions are due to economic and agronomic considerations as well as to the composition of their car industry and refinery structures for the choice of its biofuels.

In France, the original target of biofuel was to overcome the drawbacks of set-aside lands (CAP mandatory set-aside lands) decided in 1993 in order to control food supply. Rapeseed methyl ester was favored because it permitted the cultivation of the greatest area of set-aside lands for a given amount of public financial support owing to its low yield per hectare (see table 1). More recently, policies to control greenhouse gases have shed a new light on biofuels: they represent a centerpiece in the measures taken to reduce CO_2 emissions in transport.

Crop	**Sugarbeet**	**Wheat**	**Rapeseed**
Yield in tons (2005)	79.4	8.1	3.3
Evolution of yield in tons/year	0.98	0.12	0.02
Primary biofuel	**Ethanol**	**Ethanol**	**Vegetable oil**
Yield hl/hectare (2005)	79	28	15
Density	0.79	0.79	0.91
Secondary biofuel	**ETBE**	**ETBE**	**RME**
Yield hl/hectare (2005)	180	64	15
Density	0.75	0.75	0.88
Replaced fossil fuel	**gasoline**	**gasoline**	**diesel**
Liter of fossil energy replaced per liter of biofuel	0.83	0.83	0.92

Table 1: Some technical data

Two main types of biofuels are industrially produced: ETBE[23] (ethanol from wheat or sugar beet) and RME[24] from rapeseed oil (or ester) (table 1). Primary biofuels (ethanol and oil) are processed to obtain secondary biofuels which are compatible with the requirements of motors offering increasingly high performances. ETBE is mixed with gasoline, and RME is mixed with diesel. The substitution of a part of the fossil oil by RME eases the constraint on diesel supply, which is subject to the biggest increase in demand. Moreover, incorporating RME improves the lubricating quality of diesel, which has become poorer and poorer in sulphur for environmental reasons. Ethanol could also be directly mixed with gasoline, but this scenario is largely marginal: in France at present, it is excluded for technical reasons (instability of the gasoline-ethanol combination in the presence of water, which results in an increased volatility of the blend). However, these obstacles could be overcome

[23] Ethyl-Tertiary-Butyl-Ether

[24] Rapeseed Methyl Ester

quickly considering the technical knowledge of the French car manufacturers present in the big ethanol producing countries and if a specific distribution system for the gasoline-ethanol mixture was envisaged. Biofuels are a little less energy-giving than oil products, especially ethanol, hence the slight over-consumption of the blends leading to a slight economic depreciation of biofuels compared with fossil fuels. For 2005, table 1 shows the yields per hectare of primary and secondary biofuels for the three crops concerned. Rapeseed is the least productive one of them. If the upward trend in observed yields lasts (2^{nd} line), production per hectare will go on rising, but more for ethanol than for rapeseed ester. This is why the large production of ester planned in the biofuel program will take up a lot of arable lands. By way of information, palm oil production is four times higher.

2.2 Positive energy balance, but small contribution to energy independence.

The production of biofuels requires consumption of fossil energy throughout the production chain. Therefore, it is necessary to check whether biofuels will induce savings in fossil energy when they replace fossil fuels. Energy balances allow us to check this. If balances are over 1, gains in fossil energy will be higher than expenses. However, it is difficult to assess these balances because co-products are produced at the same time as these biofuels, and are used either in animal feed (DDGS[25] and rapeseed cakes) or in chemical industries (glycerol). As the productions of biofuels and co-products are closely linked in industrial processes, it is impossible to find out the real quantity of fossil energy consumed in order to obtain co-products.

In the balances presented by the Department of Energy and Mineral Resources (DIREM) and by the French Agency for the Environment and Control of Energy (ADEME), the difficulty outlined above is bypassed by adopting an accounting method (table 2, 1st column). It consists in assigning the co-products, on an inclusive basis, with a certain quantity of fossil energy consumed by the chain, according to an applied rate. This rate is the relationship between the quantities of co-products and fuels. This energy assigned to co-products is deducted from the energy assigned to biofuels, which improves, proportionally speaking, the energy balance of the latter. Other applied rates could be used resulting in other energy balances.

Energy Yields function of the methodology used for co-products		
	Accounting Method	Systemic Method
Wheat ethanold	2.04	1.19
Sugarbeet ethanol	2.04	1.28
RME	2.99	2.5

Table 2: Energy balances

Faced with this difficulty, the only satisfactory method is a systemic approach consisting in assigning co-products with the fossil energy needed to produce the goods that these co-products will replace (for instance, the rapeseed-cake from the ester

[25] Distiller's Dried Grains with Solubles, obtained during the fermentation of cereals (wheat, corn) into ethanol.

chain will replace the soy-cake imported to feed animals). Unlike the previous one, this method will measure the real effect of the insertion of a biofuel chain on the consumption of fossil energy. This method was recommended by Shapouri as early as 1995, and has been accepted for the recent study conducted by EUCAR (European Council for Automotive R&D), CONCAWE (Conservation of Clean Air and Water in Europe) and JRC (European Joint Research Centre)(table 2, 2nd column). With this hypothesis, energy yields are nowhere near as good, especially with ethanol.

Considering the biofuel needs planned for 2010 by the EU,[26] (that is to say 9.3 million hl of ethanol and 27.5 million hl of ester) and on the basis of the energy outputs in table 2, the net contribution of biofuels to oil savings is between 1.5 Mtoe (million tons of oil equivalent - substitute value for co-products) and 2.0 Mtoe (mass prorata for co-products). The ester chain has quite a good energy output per volume of biofuels but these results become very modest in terms of hectares of land. The total contribution of biofuels to oil savings is low, given that in 2004, agriculture consumed 2.9 Mtoe of final energy (all forms of energy taken into account) and France 92.8 Mtoe of oil.

2.3 The likely competition with food crops

Now that the targets of biofuel production are clearer, it is interesting to measure their consequences on the agricultural areas utilized. Table 3 shows the estimated

[26] France has since then decided to go beyond the Commission's recommendations.

needs in farming surface area to produce the quantities of energy crops corresponding to the incorporation target (suggested by the European Union) of 5.75% biofuels by 2010. Traditionally reserved for set-aside lands (main reason for their implementation), it is clear that energy crops will spread beyond this area (at present set-aside lands represent about 1.5 million hectares but the surface area may vary according to political decisions) to meet this target. In this perspective, competition might appear between food and non-food crops.

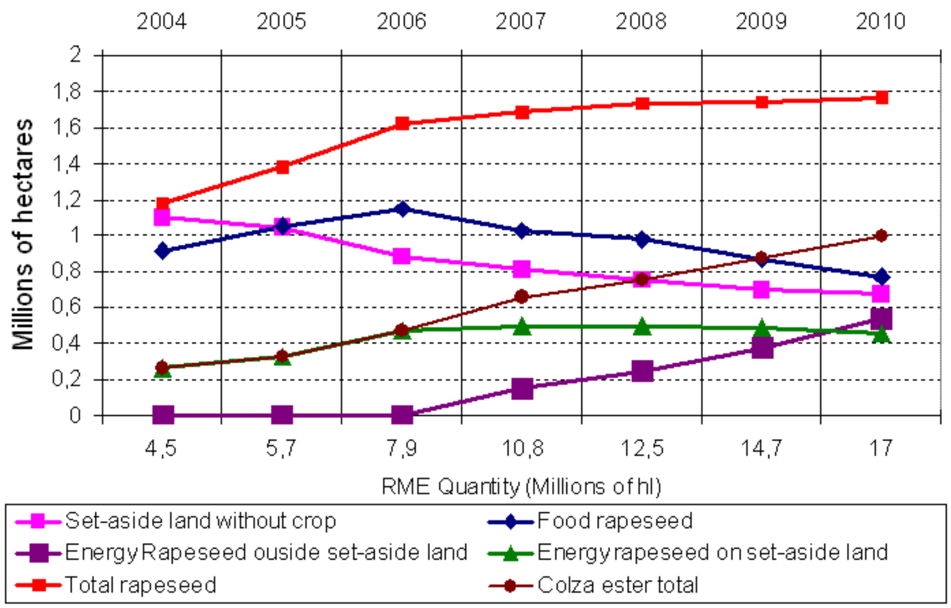
		2004	**2007**	**2010**
Needs in ethanol	Million hectoliters	2.68	5.95	9.27
Needs in RME	Million hectoliters	4.93	13.15	27.57
Needs in wheat and sugarbeet	1000 hectares	60	145	225
Needs in Rapeseed	1000 hectares	330	880	1,800

Table 3: needs in feedstock for biofuels

Studied using the INRA's sequential model OSCAR, this competition mainly arises between rapeseeds (for food and non-food use), owing to the constraints inherent to farming production, and to a lesser degree between rapeseed and cereals. This competition emerges as soon as ester production reaches 8 million hectoliters (graph 1) (which is quite soon in the increase in importance of the biofuel development program which forecasts an ester need of 27.57 million hectoliters) and before the total set-aside area of 1.5 million ha is reached (table 3: the production of 13.15 million hl of ester requires a surface area of 880,000 ha). This situation is linked to the fact that in the model, a large part of the set-aside areas is not used for non-food rapeseed crops for the following reasons: constraint of a maximum of 30% rapeseed in rotations (practices observed), 30% of the set-aside land is considered as unexploited (sloping ground, land too far away from the main body of farm, and so on) and 34% of the producers, with no experience in rapeseed, are excluded from production. Moreover, the additional aid of 45€ per hectare granted to areas switching from food crops to energy crops (up to 1.5 million ha on the European level) contributes to the substitution of food rapeseed by energy rapeseed: the rotations of crops are the same; only the use is different. The aid is justified by the fact that these productions contribute to fighting GHG emissions or even to the regulation of cereal markets (the export of cereals costs the European Union an average of 5€ per ton). The framework of this analysis is probably a little rigid. In particular, we may think that the number of rapeseed producers is likely to rise thanks to farming development programs. Even though they are slightly more profitable than food crops, energy crops cannot totally replace the latter because they are set by quotas according to the quantities of biofuel production authorized by the State.

> We assume different strong hypotheses: 1) Agricultural prices are supposed to be constant; 2) The tax exemption is limited to its minimum (see table 4); this is why, in table 6, the cost for the taxpayer is only 0.09€/l instead of the present tax exemption at 0.33€/l; 3) No significant negative effect is mentioned, either on the side of the food industries which compensate for the deficit of the national food crop production through imports at steady prices, or on the oil side insofar as the biodiesel program reduces the imports of diesel; 4) Last, the opportunity cost of public funds equals zero, which renders the strong political desire to develop biofuels.

Box 6: Hypotheses for the OSCAR model

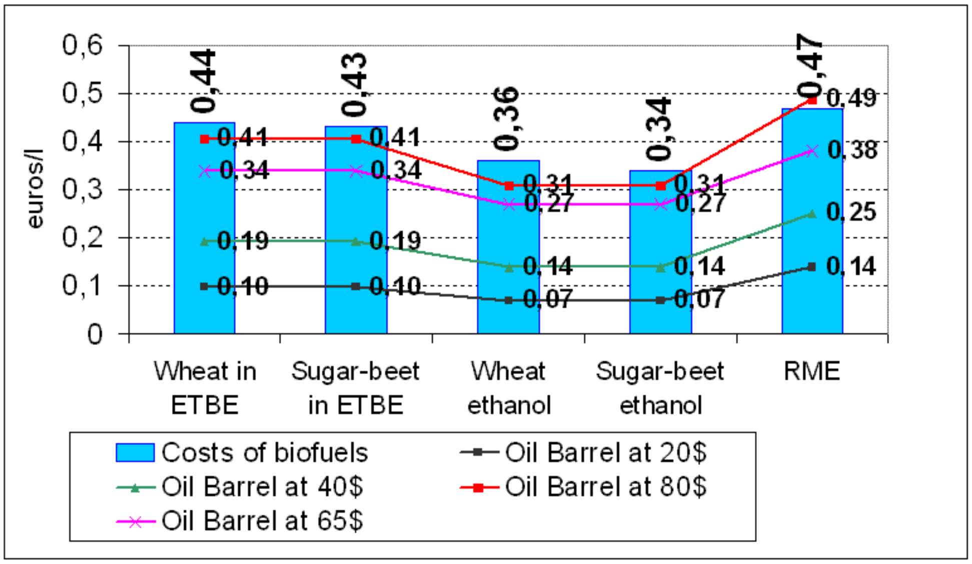


Graph 1: Area in rapeseed forecasted by the OSCAR model.

This competition could lead to a rise in food and energy rapeseed prices. In the United States, in the case of corn, Gallagher (2000 and 2003) showed that there is a possible rise in corn prices if ethanol takes the place of a large part of an additive to gasoline of fossil origin, methanol, which is suspected of environmental damage. This price rise increases corn producers' income; on the other hand, it penalizes, albeit to a lesser extent, the income of stockbreeders who are corn consumers. However, in Europe, stockbreeders and cattle feed industries could gain from the development of RME and wheat ethanol because of a fall in the price of rapeseed cakes and DDGS. This fall in the prices of co-products would make RME and wheat ethanol more expensive since the valorization of co-products is deducted from the biofuel costs. For

Europe, it would be advisable to study the effects of an ambitious worldwide production of biofuels on European agricultural prices and on the trade of farm products.

The biofuel costs plotted on graph 2 are calculated from the farm-gate to the finished product, in depots, before distribution to retailers. These costs, assessed per liter, are formed by the purchase prices of raw materials (wheat, rapeseed, sugar beets) and the logistics and industrial costs minus co-product revenues. They are drawn up in the context of competition between food and energy crops: ester rapeseed is cultivated both on set-aside lands and food plots. This competition necessarily brings the purchase costs of wheat and rapeseed energy crops at least to the level of food crops at farm-gate prices, respectively 88 and 198€/t. Because of the special quota regulations, the price of sugar beet, that is to say 20€/t, is a calculated price allowing every sugarbeet grower to profitably produce ethanol on arable lands (study carried at INRA for the reform of the sugar market in the EU). From what we know, this theoretical price is close to the actual price. This pattern of energy crop prices is plausible since, in the long run, industrial companies will wish to avoid any compartmentalization between food and non-food markets.



Graph 2: Cost and valorization for different types of biofuels produced in France

In graph 2, the economic valorizations of biofuels are given by the black curve. They are estimated when they come out of the refinery depot by applying a reduction in fuel prices in order to take into account the overconsumption by motors using additive blends of biofuels. Therefore, biofuel valorization is lower than fossil fuel price, in particular ethanol against gasoline (see substitution rates in table 1).

The comparison between costs and valorization clearly shows that biofuels are not competitive without specific support. The main biofuel, ester, would become competitive against diesel if the oil price reached 75 to \$80 per barrel (1€ = \$1.2). An increase in oil prices does not favor so much the competitiveness of ethanol and still less that of ETBE because of their poor energy balances.

2.4 An economic overcompensation through the partial exemption of "TIPP"

In addition to the agricultural subsidies granted by the CAP, biofuels enjoy a partial exemption of "TIPP" (Interior Tax on Oil Products) which applies to fossil fuels. This exemption is 0.33€/l for ester and 0.37-0.38 €/l for ethanol in 2005. This tax exemption allows biofuels to be profitable when oil prices fluctuate between 15 and $20 per barrel. Today, such a level of exemption is no longer necessary. Considering the present oil context and the previous hypotheses on the prices of energy crops (that is to say prices equivalent to the corresponding food crops), the minimum exemptions that should be implemented may be assessed by the gap between biofuel costs and their increase in value such as they are on graph 2. For an oil price of $65, these exemptions are more or less equivalent between ETBE, ethanol in direct use, and ester. Given that the tax exemption concerns ethanol, and that from a liter of ethanol you obtain 2.27 litres of ETBE, the tax exemption per liter of ethanol more than doubles for that chain. This estimation can be seen in table 4, for an oil price of $65 a barrel. The minimum exemptions are much lower than the current ones, especially for the chains of ester and ethanol in direct use. They are higher for ethanol via ETBE because of the additional cost of ETBE production.

	Minimum tax-cut, €/hl, $65/barrel oil	**tax-cut €/l (2005)**	**Excess tax-cut €/l**
Wheat ethanol used in ETBE	0.22	0.38	0.16
Sugarbeet ethanol used in ETBE	0.20	0.38	0.18
Wheat ethanol, direct use	0.09	0.37	0.28
Sugarbeet ethanol, direct use	0.08	0.37	0.29
Rapeseed methyl ester	0.09	0.33	0.24

Table 4: Excess in tax-cuts

The tax exemption surpluses presented in table 4 give an estimate of the profits for the agents involved downstream, from collection through to incorporation of biofuels into fossil fuels. It is logical to compare these gains with those of agriculture. We should remember that, in 1993, agricultural objectives were clearly displayed to justify the development of biofuels.

The sharing of profits in favor of agriculture essentially depends on two factors: the agricultural prices of energy crops and the nature of the areas used for these crops (CAP set-aside lands or areas given over for food production). The prices which will be used to estimate this sharing are the ones which were used for the estimation of biofuel costs (graph 2), that is to say 198€/t for rapeseed, 88€/t for wheat and 20€/t for sugar beet, as explained above. These prices apply whatever the location of the energy crops, on CAP set-aside or on arable lands. To meet the demand for energy crops, farm producers will first put a part of the CAP set-aside land into cultivation again (graph 1) before replacing food crops, because this choice is economically more interesting. This substitution for set-aside land will last as long as the impact on farm incomes are greater than the bonus of 45€ per hectare granted when energy crops replace food crops. This is why, at present, the 300,000 hectares of rapeseed ester almost totally fall within the set-aside lands. The profit sharing results (given in table 5) are based on this mechanism.

As long as energy crops replace CAP set-aside lands (table 5), farm producers get additional farm income per hectare of wheat or rapeseed ranging from 200 to 300€; these incomes are more or less equivalent to the average income per hectare of cereal farm-holdings. In this way, farmers retrieve the part of income lost due to the CAP provisions on set-aside lands enforced in 1993. The increase in farming income per hectare of energy sugar beet exceeds the increase in income of other crops because of the methods used to estimate prices; it is the opposite per liter of biofuel because of the high production of ethanol per hectare of sugar beet (100 liters/ton). A comparison of these agricultural gains with the downstream ones requires an expression of the supplementary farm income per liter of biofuel. We can see that the additional farm income per liter of biofuel is quite clearly lower than downstream gains produced by the tax exemption surpluses.

	Price	**Average yield**	**Increase in agricultural income (energy crops produced on set-aside land)**		**Increase in agricultural income (energy crops competing with food crops**		**Excess tax-cuts**
Units	€/ton	t/ha	€/ha	€/l	€/ha	€/l	€/l
Wheat	90	8.22	302	0.10	45	0.02	0.16
Sugarbeet	20	79.5	606	0.08	149	0.02	0.18
Rapeseed	200	3.28	199	0.08	45	0.03	0.24

Table 5 ; Increased agricultural income on and outside the set-aside land

As soon as these crops replace food crops, the economic benefits for agriculture diminish sharply. The increase in farming incomes per hectare of wheat and rapeseed falls to 45€ (aid to energy crops) and that of sugar beet to 149€. The gain per liter of biofuel becomes very low (0.02-0.03€/l). Profit sharing between agriculture and the downstream sector is unequitable in this scenario.

To summarize, as long as biofuels allow farmers to cultivate their CAP set-aside lands, the situation is interesting for them; on the other hand, when energy production starts to whittle away food areas, the economic stakes become quite marginal. It must be added that the economic spin-offs of biofuel chains chiefly concern the cereal regions, which are generally well-equipped in agro-industrial structures, and much less the mixed farming regions.

2.5 Costs and benefits of the biofuel program

An estimate of the impacts of the biofuel program on general economic activity and among other things, on job creation, is a very controversial issue. PriceWaterhouseCoopers announces the creation of 3,800 jobs and added value of 207 million € induced by the present biodiesel program (about 4 million hectoliters). For the American Midwest and for a production of 14 million hectolitres of ethanol, Gallagher indicates 5,500 jobs created in industry and services – but few in agriculture – and a positive balance of $200 million.

In the case of industries, the analysis only considers the jobs and the added value created at the level of the industries grinding rapeseed and esterifying oils. The tax exemption being set at a minimum compatible with the microeconomic balance of the chains, the industrial added value is equal to the remuneration of fixed factors of the biofuel industry, that is to say the salaried costs of the created jobs and the other fixed costs. In the case of the farming sector, the analysis only considers the farming incomes and jobs provided by the proportion of crops cultivated on set-aside lands. We assume that only the energy crops on set-aside lands are likely to create jobs and generate additional incomes. As a matter of fact, in the case of energy crops replacing food crops, there is no reason to foresee any economic boost effect through increased consumption of farm inputs, the inputs for non-food crops being the same, in nature and quantity, as the ones used by substituted food crops.

Box 7: Hypotheses for the Cost-Benefit analysis

On the other hand, a study by the Department of Budget of the French Ministry of Finance (Lévy-Couveinhes report, July 2000) leads to negative macroeconomic conclusions unless the oil price reaches at least $60 a barrel, and contests the job creations resulting from sector-based measures. These large differences in results stem on the one hand from divergent methods, and on the other hand from whether or not the opportunity cost of public funds (consideration of alternative uses of public money intended to support biofuel chains) is taken into account. The macroeconomic models which would allow a more in-depth analysis of the production of energy from biomass because they are free of these simplifying hypotheses are not yet up to scratch. Using the OSCAR model, we therefore carried out a very simplified analysis of the macroeconomic effects originating from the biodiesel chain for a program of 27.5 millions hectolitre (needs of 2010) (see the appendix). The results come to 1,800 jobs created, including 300 maintained in agriculture, and added value of 0.09€ per liter of biodiesel. Taken as a whole, these impacts are quite weak because of the competition between food and non-food crops. Finally, all these elements put end to end give the balance in table 6 which concludes that the situation is balanced. To the strictly economic results above, we must add the positive environmental externalities coming from the reduction of GHG. At present, the monetarization of this advantage is made easier by the existence of a market for the rights of CO_2 emission, the price of which is around 20€/t CO_2. However, this evaluation remains virtual since it relies upon a fluctuating market of emission permits and not on the real damage caused by greenhouse gases. The results below are obtained from life cycles analyses made by ADEME and DIREM (see table 7).

Cost-benefit in €/l, RME chain, 2010 situation, $65/barrel	
Minimum tax cut (loss in taxpayer's surplus)	-0.09
Variation of GDP, biofuel industries	0.05
Variation of agricultural surplus	0.04
Sum	0

Table 6: Cost-benefit analysis

The valorization of CO_2 helps to justify only a part of the public funds granted to the biofuel chain. By placing itself at this second level of analysis, the biodiesel chain, an essential link in the biofuel program, is in the general economic interest thanks to its positive contribution to the reduction of greenhouse gas emissions. However, this result is closely linked to the given oil price of 65$ a barrel. A drop of only 10% in the barrel price would lead to the cost-advantage balance in table 6 becoming negative and cancelling out the positive effect resulting from the reduction of greenhouse gas emissions shown in table 7.

	Teq CO_2 saved per hl	**Amount €/hl**	**in % of the minimal tax-cut**
Wheat ethanol in ETBE	0.22	0.02	9
Sugarbeet ethanol in ETBE	0.22	0.02	10
Wheat in ethanol, direct use	0.10	0.04	46
Sugarbeet in ethanol, direct use	0.10	0.04	57
Rapeseed methyl ester	0.21	0.04	49

Table 7: the CO_2 externality

Conclusion

First-generation biofuels constitute a fairly ineffective energy production. This was acknowledged in 2004 by the American National Commission on Energy Policies which recommended abandoning corn ethanol for ligno-cellulose ethanol. It is too early to say whether this result can be extrapolated to France. The results of the national research program on the valorization of biomass which has just been launched should bring new developments on this matter. If the “non-food” sector encroaches on the “food” sector – as is more than likely in the future – the microeconomic accounts of biofuels are in deficit, even if the price of oil reaches \$65 a barrel (1€=\$1.22). In other words, public aid is necessary for the economic balance of the chains. However, the present support granted in the form of a "TIPP" exemption could be notably reduced, given the high prices of the oil barrel, especially in 2005.

The microeconomic competitiveness of biofuels requires high oil prices of between 75 and \$80 per barrel. The maximum price of oil (Brent), which was reached in 2005, is lower than this. The high 2005 prices resulting from an increase in the demand for oil may favor capacity investments; a decrease in oil prices could result from this, which would automatically increase the microeconomic deficit of the biofuel chains. The International Agency for Energy, in the World Energy Outlook of 2004, suggests a scenario of the oil price at \$35 a barrel in 2030 (in constant dollars 2000). According to the Agency, this average price level remaining steady over a long period would lead to investments allowing a structural change in energy demand, including a reduction in world energy demand for oil of up to 15% (that is to say the equivalent of the present demand from the United States). This hypothesis of the long-term lowering of prices results from the level of reserves, the progress in oil extraction technologies, the promotion of new sources of non-conventional oil (asphalt sands, heavy oils) and from the large reserves of energy savings.

The microeconomic repercussions for farm producers are above all tangible as long as the set-aside lands are valorized; beyond, these repercussions decrease sharply. These repercussions chiefly concern the large cereal regions of the North Paris basin and much less the mixed farming regions. This is why the production of oil in rural plants for direct use in fuel could develop after the recent withdrawal of a certain number of statutory obstacles. In the mixed farming regions, it could become a way of creating added value at the local level and reinforcing the links between cereal growers and stockbreeders in the same region within the framework of the implementation of "traceable" animal chains.

In fact, an ambitious biofuel program such as the one proposed for 2010 is much more of an economic challenge for "biofuel-oil industries" than it is for farmers, unless a driving effect on agricultural prices occurs. Considering the importance of the biofuel programs which are implemented not only on the European level but also on a worldwide level (Brazil, USA for ethanol, Malaysia-Indonesia for palm oil), this positive effect may be possible.

Macroeconomic assessments shed a more favorable light on biofuels. Very positive for certain authors (PriceWaterhouseCoopers, Gallagher), they merely seem satisfactory according to our estimations. These broad economic results are positive provided that the oil price reaches \$65 a barrel and that the monetary value of the reductions of CO_2 emissions is taken into account. However, at present this sole valorization is not enough to justify public support. The production of biofuel restricted to the set-aside lands would have benefited from much more flattering economic assessments (but it cannot achieve the objectives of the European Union).

In the final analysis, the economic and energy balances of first-generation biofuels are not decisive enough to make these renewable energies an alternative anything more than limited to the exhaustion of oil resources. Under these conditions, like in the United States, the second-generation biofuels using ligno-cellulose resources, by-products and crops bring much more hope. In fact, they could need less land, improve energy outputs and benefit from lower costs. In the first place, a stock of 5 million tons of wheat straw (that is to say a quarter of the annual French production of cereal straw) is available, while preserving the fertility of the soil and the demand of stockbreeders. This resource of 1.5Mtoe primary energy would supply enough ethanol to meet the needs of 2010 such as they are stated by the European Union. The wood-chain by-products could also increase the stock of biomass, while extending the areas of biofuel production. Later, dedicated crops (specific cereals, miscanthus, quick-rotation coppice) are envisaged. In addition to the European programs, a research effort on the national level has recently been launched on the matter. Within 10 to 15 years, the first technologies for the conversion of biomass into biofuels should see the light of day.

Update on the production costs of biofuels

The prices of oil and agricultural commodities have drastically changed since this study was conducted. However, biofuels are still not profitable, as our lastest calculations show (as of January 2008):[27]

	Private production cost	Public production cost, CO_2 priced at 20€/t	Public production cost, CO_2 priced at 50€/t
Wheat ethanol	0.67€/l	0.63€/l	0.57€/l
Rapeseed biodiesel	0.80€/l	0.75€/l	0.69€/l

Table 8 ; Private and public production costs for biofuels

	Threshold oil price
Wheat ethanol	183$/b
Rapeseed biodiesel	147$/b

Table 9 ; Oil price for biofuel profitability

This situation is straightforward to explain. Take the example of vegetable oils, which are used to make biodiesel. Upon the last three years, their price evolution has been following the (fossil) oil price. In such a context, biofuel industries will never be profitable: the increase in their output price is offset by the increase in their input price. As agricultural and energy prices have been linked by the production of biofuels worldwide, biofuel industries will almost always require support schemes (tax-cuts or mandates) in order to break even.

[27] The prices of commodities were the following: wheat at 230€/ton and rapeseed at 400€/ton. The €/$ parity was 1€=$1.47

The global energy situation has profoundly changed since the beginning of years 2000, characterized notably by the all-time record (in nominal terms at least) set by the oil barrel in the first days of 2008. This recent evolution hinges upon three main factors: the unexpected rise in demand, insufficient production capacities and the deregulation of the energy sector. However, the end of the nineties had been characterized by a cheap and aboundant energy: the oil barrel was oscillating between \$15 and \$25 by then. Energy and economic development are two intertwined notions. Besides, the global energy consumption is affected by the great politicals events, as the two oil shocks that took place in the seventies demonstrate. During this period, the oil barrel has surged from \$3 in 1973 to \$30 by the beginning of the eighties. However, the counter oil shock in 1986 pulled this price back to \$10. More recently, the collapse of the USSR or the monetary crisis in the emerging Asian countries (1997-1998) has heavily weighted on the global energy market. In spite of these sporadic variations, the long term trend remains upward-oriented. Oil accounts for 35% of the global energy production, while coal and natural gas respectively make up 23 and 21% of the total production. The various scenarios of the evolution of the global energy demand hinges on two main factors: economic growth and the degree of environmental protection laid down by the states. All the scenarios converge to a decrease in the energy intensity and a landscape in which fossil energy will still be dominating. Oil's share will rise to 40%, with an increase from 3.8 to 5 Gtoe (Giga ton of oil equivalent) in absolute terms. The first three producers of oil are Saudi Arabia (which takes up a central position within the OPEC cartel), the former Soviet Union (which used to be the biggest producer during the eighties) and the United States. The difficult question of the world's oil reserves should not be taken up without a few definitions. First of all, a distinction should be drawn between the notion of resource (the volume of oil underground) and reserve (the quantity which can effectively be recovered, depending on the available techniques and the production costs). These reserves can be proved, probable or possible, the difference lying in the degree of certainty concerning their effective exploitation. Experts at the French Petroleum Institute estimate that the proved reserves of conventional oil add up to 40 years of consumption. These reserves could be revised upwards following discoveries, a better knowledge of the existing oilfields and thanks to a better retrieval of oil. We should also add on the non-conventional oil reserves (extra-heavy oil, asphaltic sands and bituminous schists). Oil prices have evolved in a rather sudden trend, surging from \$10 in 1998 to \$100 in 2008. The explanations classically put forward to explain such a huge increase are the high demand for oil (stemming from a vigorous global growth), the vanishing of the production excess, concerns on the reserves and some degree of speculation. However, we should note that the prices are largely greater than the production costs: \$3 in Saudi Arabia and a maximum of \$15 for the most expensive oils to extract. Moreover, producer countries make their budgetary forecasts based on a barrel which seldom exceed \$30 ; oil companies make their investment decisions based on a threshold price for oil ranging between \$20 and \$30. The importance of oil in the economy has been drastically reduced since the seventies, when the tenfold multiplication of the barrel price had triggered a 15% decrease in demand. The high prices observed during the present decade have had far less consequences. In the medium term, the barrel ought to pull back around \$30 to \$40 per barrel. The challenges that crop up with global warming calls for a major cut in the consumption of fossil energy, an increased use of carbon-free energy and a control of the global energy consumption. Finally, the contribution of biofuels to the efforts to tame climate change remains very modest (in 2007, biofuels amount to only 1% of the global demand for fuels).

Box 8: Oil and energy markets. This is the summary from an article by Favennec, J.-P. entitled "Energie : demande, réserves, capacités de production et prix", published in the Biofuel Survey under the supervision of Tréguer, D., Déméter 2008, 352 pp.

GHG emissions: an update on methodology.

Crops for biofuels in the EU have historically been produced on set-aside land. Hence biofuels made from crops produced on this unused arable land permits to save GHG emissions with respect to the fossil fuel alternative. The results of life-cycle analysis studies showed a great heterogeneity, but the commercial processes in the EU enable to reach GHG savings between 18 and 50%. The agricultural production, the industrial transformation of crops into biofuels and the final use in cars lead to GHG emissions of the same magnitude or even greater than their fossil counterparts. However, biofuels are granted with a carbon credit since their use prevents the release of carbon dioxide from fossil fuels, which are kept underground. Thanks to that carbon credit, biofuels have lower life-cycle emissions than petroleum fuels. This framework for assessing biofuels GHG emissions was acceptable as long as biofuels were incorporated in small quantities. With the new 10% target set for 2020 in the EU, a more complex analysis ought to be conducted, taking account of the land-use changes triggered by this high incorporation rate. As pointed out by Fargione *et al.*, the sizeable production of biofuels on a global scale will lead to the conversion of land (mainly in the Americas and Southeast Asia) for biofuel production (or food/feed production when the existing agricultural land has switched to biofuel production). The conversion of land within previously undisturbed ecosystems will lead to large CO_2 emissions stemming from the burning and microbial decomposition of the organic carbon sequestered in the soil and plants. Hence, it seems necessary to consider these indirect GHG emissions linked to biofuel programs in the EU. This CO_2 emission takes place in two steps:

- First, a rapid release occurs with the fire used to clear land and the decomposition of leaves and fine roots
- Then, a long period of GHG release ensues, stemming from the decay of coarse roots and wood products.

The total quantity of CO_2 released over the first 50 years is denominated "carbon debt" by Fargione *et al.*

Thereafter, as time goes by, biofuels may possibly repay this initial carbon debt incurred at the initial land conversion stage: this is of course only possible if the production and combustion of biofuels lead to lower life-cycle emissions than the fossil fuels they replace. However, it seems worth stressing that until this debt is eventually repaid, biofuels produced on converted land lead to higher GHG emissions than fossil fuels. When these indirect effects are properly accounted for in the GHG analysis, the positive externality of biofuels turns out to be a negative environmental externality.

The emissions linked to land use changes (grassland, tropical forest or savannas to cropland) must therefore be properly taken into account. Table A below shows different cases of land conversion and the associated carbon debts. The worst type of biofuel in that respect is biodiesel made from palm oil grown on land previously planted with tropical rainforest on peatland (in Malaysia or Indonesia), which incurs a carbon debt that would take 423 years to repay. The quantity of carbon released when palm trees replace peatland is increased by the need for drainage, which leads to additional sustained emissions of 55 Mg of CO_2.ha^{-1}.yr^{-1}. With the importance of the EU biodiesel program, there will be a need for vegetable oil imports. These imports will either come from South America (Brazil and Argentina) and South-east Asia (Indonesia and Malaysia). Judging by the figures in table 10, the indirect carbon emissions linked to the EU biofuel program could have extremely negative consequences: the production of palm oil in Indonesia/Malaysia would require between 86 to 423 years to repay the carbon debt, while the production of soybean in Brazil for biodiesel necessitates between 37 and 319 years to balance the initial carbon loss. These new analyses tend to jeopardize the EU 10% target by 2020. Besides, it seems that biofuel certification cannot solve the problem, as the enforcement issue on a global scale seems hardly feasible.

Biofuel	Palm biodiesel	Palm biodiesel	Soybean biodiesel	Sugarcane ethanol	Soybean biodiesel
Former Ecosystem	Tropical rainforest	Peatland rainforest	Tropical rainforest	Cerrado wooded	Cerrado grassland
Location	Indonesia and Malaysia	Indonesia and Malaysia	Brazil	Brazil	Brazil
Carbon debt (Mg $CO_2e.ha^{-1}$)	702	3452	737	165	85
Debt allocated to biofuel (%)	87	87	39	100	39
Annual repayment (Mg $CO_2e.ha^{-1}.yr^{-1}$)	7.1	7.1	0.9	9.8	0.9
Time to repay biofuel carbon debt (yr)	86	423	319	17	37

Table 10 ; Carbon debts from different land conversions for biofuels ($Fargione\ et\ al.$)

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Part II A necessary evolution of agricultural and environmental policies in the new biofuel context

The recent impulse given to biofuel energy policies is likely to produce major side-effects on highly regulated agricultural sectors, particularly in the European Union (EU) and in the United States (USA), where public regulation of the agricultural sector is prominent.[28] Since the new biofuel policies might trigger feedstock price increases, biofuel policies will have interactions with agriculture policies aiming at supporting farmers' income. Additionally, as most of the energy crop production might lead to more intensive agricultural practices, they will interact with environmental policies directed at agriculture as well. In countries where agricultural policies aim at supporting the farmers' income, the question of a dual support for the agricultural sector (biofuel support in addition to the "traditional" income support schemes) might lead governments to take advantage of the possible substitution between these

[28] We curtail our analysis to the first generation of biofuels, which uses the same feedstock as the agro-food industry. Moreover, the interactions with energy markets, although very interesting, will be left aside in this analysis.

two kinds of supports (Babcock, 2007). For the EU, sorting out the environmental consequences of the development of biofuels is further complicated by the links between income support and environmental objectives of agricultural policies (the so-called “cross-compliance” provisions). In the USA, the question of environmental impacts of energy crop production, although not directly linked to income support as in the EU, is also an important issue. The increased production of corn might well lead to local pollution problems, as well as soil erosion concerns.

Hence, the emergence of biofuel policies marks a profound change in the path of agricultural policy reform, which has mainly consisted in decoupling the support awarded to farmers from production decisions. This evolution has begun with the 1992 reform and was further reinforced during the Agenda 2000, Mid-Term Reform in 2002 and the "Health-Check" which ought to be adopted prior to the end of 2008. Clearly, the decision to design large-scale biofuel programs has led to sharp increases in agricultural commodity markets, and this new biofuel policy, although formally taking place outside the CAP, has deep consequences on the logic of the evolution of the CAP. It could be argued that biofuel policy has implications that look like re-coupling. Moreover, the evolution that had been observed with respect to the enforcement of environmental policies within agricultural production is jeopardized by the high price levels triggered by biofuel programs. The reforms of the Common Agricultural Policy had led to the implementation of cross-compliance provisions, with the possibility for the regulator to fine the farmers in case of infringement, the penalty paid by the farmer being proportional to the decoupled payment. With a new framework of high commodity prices and decreased decoupled payments, the cross-compliance scheme is put at risk. A new scheme ought to be implemented in order to guarantee that the progress achieved during the successive CAP reforms environment-wise will not be cancelled out by the new conditions of agricultural production, i.e. high prices which are an incentive for farmers to increase the use of polluting inputs, e.g. fertilisers and pesticides.

Chapter 3 is dedicated to the analysis of the interactions between biofuel and agricultural policies, more precisely on the likely evolution of the latter in the new context of high agricultural prices triggered off by sizeable biofuel plans. We will show how a partial substitution of support to the biofuel industry (in the form of subsidies or mandates) for agricultural decoupled payments could lead to a higher aggregate welfare situation. *Chapter 4* addresses the question of the enforcement of environmental provisions in agriculture, in the context of an increased production of energy crops. The main question raised in this chapter consists in selecting the best penalty scheme in the new biofuel context, i.e. either a fraction of the decoupled payment (the scheme used under the current CAP framework), or fixed penalties.

Chapter 3
Biofuels production and the economic support to agriculture

Introduction

In the EU as in the USA, a major part of the programs aimed to develop biofuels have been set up under the pressure of agricultural lobbies who conceive biofuels as an opportunity to stem the tide of decreasing incomes. By subsidizing the biofuel industry, the regulator raises the (internal) price of the agricultural feedstock. In the EU, a development of biofuel production allows the agricultural sector to benefit from a dual support (taken in a broad sense): on the one hand, the State hands out decoupled payments to farmers (Single Farm Payments), and on the other, the State gives an important support to the biofuel industries, whose production costs exceed the price at which they can sell their output. The price increase of the agricultural commodities raises the farmer revenues, and the need for direct income support is reduced. Hence, for a given objective of agricultural income, the regulator is able to operate a partial substitution between direct agricultural income support and subsidies to the biofuel industry. Owing to the importance of the Common Agricultural Policy (CAP) in the EU budget (€50 billion per year, i.e. 46% of the EU budget), and since the support to agriculture is twofold (CAP payments and biofuel subsidies), the question of a partial substitution of biofuel subsidies for CAP payments could be on the EU political agenda very soon.[29] In the USA, the ethanol program might lead to a long-lasting price increase for corn, wheat and soybeans, which could temporarily stop the counter-cyclical and loan deficiency payments (Babcock, 2006. See also the last line of table 3).[30]

The agro-food industry will face new competition from the biofuel firms for agricultural raw material. The fiercest competition will take place on the European rapeseed market. This crop is interesting for agro-food firms (among its many physical and chemical properties is the presence of omega-3) and biofuel firms alike (the iodin number of rapeseed oil is low enough to meet the specifications of fuels). Thus, both industries will find only imperfect substitutes for rapeseed.[31] Of course, this competition with biofuel firms for the same input is harmful for the European agro-food industry, which stands up against the policy in favor of the first generation of biofuels (cf. Unilever, 2006, Forbes, 2006 and Confederation of the Food and Drink Industries of the EU, 2006). Goldman Sachs (Financial Times, 2006) also points to a possible decrease in agro-food firm profits owing to biofuel production. With rising revenues for farmers, decreasing profits for the agro-food industry and a reduced consumer surplus, the net effect on European welfare is unclear.

[29] This policy could also transfer the burden of the financial backing of agriculture from the EU to the Member States, extending the "subsidiarity of the CAP" introduced by the "modulation" features of Agenda 2000.

[30] A counter-cyclical payment is a form of agricultural subsidy used to compensate farmers if the price of an agricultural commodity drops below a level deemed to be desirable. A loan deficiency payment is paid to the producers of certain commodities. It is based on the difference between a target price and the domestic market price.

[31] Rapeseed is produced elsewhere in the world (e.g. Canada produces canola, which is very close to rapeseed). However, it seems impossible to guarantee the absence of Genetically Modified Organisms (GMOs).

The first part of this chapter gives some quantitative effects on agricultural markets triggered by the development of biofuels, while the second part will address explicitely the interactions between agricultural and biofuel policies, through the presentation of a stylized model.

3.1 The effects of biofuel development on agricultural markets

Biofuel policies are likely to have large impacts on agricultural policies. First, the new demand for feedstock might lead to price increases on the agricultural markets. When reflecting on the consequences of biofuel development on agricultural policies, the first questions that come to mind deal with the evolution of agricultural markets: the prices of the main agricultural commodities. The answers to these questions are given by agricultural prospective models. In spite of the great interest that these questions take on for the actors in the agricultural sector, the study of the relationships between biofuel and agricultural policies ought to go further than the mere confrontation of supplies and demands. Indeed, the demand for energy crops is supported by the State (either directly through subsidies or indirectly through mandatory blending that weigh on the consumers). Through the enforcement of a biofuel development policy, the State triggers welfare variations (positive or negative) for the different agents involved: here lies the interesting economic aspect to be studied.

3.1.1 Model simulations for the EU biofuel sector

Several authors have attempted to gauge the future developments of biofuels in the EU, even though there is still a lack of models that fully include the linkage with the energy markets. For instance, Dronne and Gohin (2006) estimate the variation of several crop prices resulting from a demand shock of 3 million tons (Mt) of rapeseed oil provoked by the EU biofuel policy. Compared with the baseline (2002), this would lead to an increase of the EU-15 production of biodiesel from 1.1 Mt to 4.1 Mt. Although inferior to the quantity corresponding to the EU 5.75% objective (11.4 Mt of biodiesel), this quantity represents the installed capacity by the beginning of 2007. It is sufficient to assess the main impacts on the international markets. The results are presented in the following table.

Commodity	**Price variation**
Rapeseed oil	19%
Other oils	9.6/11%
Rapeseed Cakes	-5.2%
Other Cakes	-0.6/-3.5%
Rapeseed grain	12%
Other vegetable grains	3.3%
Cereals (EU)	0
Cereals (World)	3%

Table 1; Dronne and Gohin (2006)

The demand shock leads to more expensive vegetable oils, grains and cereals, while the price of cakes[32] would decrease. More recently, Gohin conducted a general

[32] Cakes are co-products of the biodiesel production process, used to feed animals owing to their high protein content.

equilibrium analysis of the European biofuel sector. The results are shown in the table below:[33]

	Soft wheat	Rapeseed	Sugar beet/ sugar	Rape oil	Rape meal	Palm oil
Production (Million tons)	93,545 (5.4%)	7,207 (76.6%)	13,877 (13%)	3,357 (68.9%)	3,955 (68.8%)	0
Total demand (Million tons)	76,833 (19.5%)	8,400 (68.9%)	13,095 (14%)	2,485 (310%)	4,478 (23.4%)	3,631 (-6.2%)
Net exports (Million tons)	17,413 (-58.2%)	-469 (0%)	430 (-7.4%)	905 (-584%)	-62 (-3,062%)	-3,631 (-6.2%)
World prices ($/T)	128 (11.3%)	245 (42.6%)	281 (0.1%)	570 (47.9%)	129 (-12.4%)	548 (38.9%)

Table 2; Gohin (2007)

The two most important results are the increase in the world price of oilseeds and the change in the EU situation, which becomes a net importer of rapeseed (from a situation of net exporter).

3.1.2 Model simulations for the US biofuel sector

For various levels of the Renewable Fuel Standard (RFS), Marshall and Greenhalgh (2006) estimate the economic impacts on feedstock prices, as well as on the incomes of various types of farmers: corn or soybean producers and animal breeders. The first subgroup might benefit from the ethanol policy, while the two other subgroups might lose money.

[33] The scenario is a production of biodiesel and ethanol at the EU-15 level in order to reach 5.75% of biofuels in 2010.

Annual production, ethanol	**Billion gallons**	**5**	**7.5 (current RFS)**	**10**	**12.5**	**15**
Economic impacts		Baseline				
Price of corn	$ per ton	94.5	3.3	7.9	12.1	17.5
Price of soybeans	$ per ton	206	-0.4	-1.6	-2.7	-3.6
Farm income	$billion per year	75	0.7	0.7	1.9	3.3
Cash receipts	$billion per year	208	0.7	1.1	1.9	3.0
Variable costs	$billion per year	133	0.6	1.3	1.9	2.9
Farm income (corn)	$billion per year	16	3.7	8.5	18.0	30.6
Farm income (Soybeans)	$billion per year	5	-2.2	-7.4	-12.2	-16.3
Farm income (Livestock)	$billion per year	47	0.5	-0.4	-0.9	-2.3
Government payments	$billion per year	10	-7.5	-15.9	-17.5	-18.4

Table 3; Marshall and Greenhalgh (2006)

This study shows that a significant development of biofuels could lead to a decrease in the federal payments directed to the farmers (Contracyclic Payments and Loan Deficiency Payments). It seems therefore straightforward that the payments given out to support biofuel production partially substitute for agricultural payments. The decrease in the price of soybeans seems quite puzzling. This decline is maybe exaggerated and stems from the fact that biodiesel development in the USA and in the EU is not accounted for in their model.

Still for the USA, Elobeid *et al.* (2006) calculates the corn price at which the incentive to expand ethanol production disappears (i.e. the maximal expansion of ethanol production). With the current ethanol tax policy and with the prices of crude oil, natural gas and co-products set at their 2006 levels (notably, a $60 oil barrel), they conclude that the break-even corn price would be $159 per ton. With this price of corn, ethanol production would reach 1.19 billion hectoliters per year, requiring 38.2 million hectares of corn. This situation is compared with the baseline for 2015 (see Elobeid and Tokgoz, 2006). Their results are described in the following tables.

		CARD Baseline (2015)	Long term	Variation (%)
Corn price	$/ton	100.8	159	58%
Corn area	Million hectares	31.8	38.2	21%
Corn production	Million tons	331	398	20%
Corn for ethanol	Million tons	82.6	282	242%
Ethanol consumption	Million liters	35,800	119,000	232%

Table 4; Elobeid *et al.* (2006)

As regards soybean, the prices ought to decrease (the increase in the soy oil price is not enough to make up for the fall in the soycakes' price, challenged by DDGS[34]). However, the analysis does not take into account the biodiesel production build-up in the USA. The negative impact on the soybean complex might therefore be over-estimated.

[34] Distiller's Dried Grains with Solubles, which is a co-product from ethanol production.

		CARD Baseline (2015)	Long term	Variation (%)
Soybean price	$/ton	203	192	-5%
Soybean area	Million hectares	27.4	23.7	-14%
Soybean production	Million tons	82	70.7	-14%
Domestic use of soybean	Million tons	57.6	50.3	-13%
Cake price	$/ton	160.2	92.7	-42%
Use of soya cake	Million tons	37.6	15.2	-60%
Price of soy oil	$/ton	535	650	20%

Table 5; Elobeid *et al.* (2006)

Besides, we should note that Elobeid *et al.* finds in its sensitivity analysis that a +/- $10 variation of the oil barrel would change its results in a rather drastic way. Thus, the following table shows the impacts of oil price scenarios on the US ethanol production and corn feed use.

			Variation w.r.t. long term scenario	
Scenario	Ethanol production	Corn feed use	Ethanol production	Corn feed use
	Million liters	Million tons		
$70 barrel, $187/ton Corn	165,106	76,3	40%	-26%
$50 barrel, $132/ton Corn	72,164	127	-39%	24%

Table 6; Elobeid et al. (2006)

			Variation w.r.t. long term scenario	
Scenario	Ethanol production	Corn feed use	Ethanol production	Corn feed use
	Million liters	Million tons		
No tariff, no subsidy	27,019	155.6	-77%	52%
No tariff	115,690	102.8	-2%	0%

Table 7; Elobeid et al. (2006)

Finally, the last table shows in a blatant manner the strong influence exerted by the economic instruments (subsidies and tariffs) on the system's durability. Without support, the biofuel development framework would be altered in quite a radical way:

- The tariff's removal hardly changes the production of ethanol (the production subsidy being maintained).

- However, when the production subsidy is also withdrawn, ethanol production falls sharply (-77%), releasing important quantities of corn for feed use (+52%).

3.1.3 Global models of biofuel production

Schmidhuber (2006) also gives a global outlook of the price evolutions for some agricultural commodities associated to an increase of 10 million tons of different biofuel feedstocks, as reported in the table below.

	10 additional million tons of...				
Commodity	Sugar	Corn	Sugar and Corn	Soybean and Corn	Sugar, Corn and Soybean
	used to produce biofuels,				
	would change world price in the long term (%)				
Sugar	9.8	1.1	11.3	2.3	13.8
Corn	0.4	2.8	3.4	4	4.2
Vegetable Oil	0.3	0.2	0.2	7.6	7.8
Proteins	0.4	-1.2	-1.2	-8.1	-7.6
Wheat	0.4	0.6	0.9	1.8	2
Rice	0.5	1	1.2	1.1	1.4
Wheat	0	0.2	0.2	0.4	0.4
Poultry	0	-0.4	-0.4	-2.1	-2

Table 8; Schmidhuber (2006)

It can be noted that the decrease in the price of proteins is more important in the case of a biofuel production made from protein-rich agricultural raw materials (soybean and corn mainly). In this case, Schmidhuber's simulations show that the price of poultry (which requires important quantities of protein for its feeding) would decrease (-2%).

The biofuel production scenario IFRI-IMPACT gives the following price increases for the main biofuel raw materials. The authors have built an "agressive growth" scenario for biofuels, i.e. they would replace (at a global scale) 10% of fossil fuels in 2010 and 20% by 2020.

	Variation in the world prices	
Raw material	**2010**	**2020**
Cassava	33%	135%
Corn	20%	41%
Oilseeds	26%	76%
Sugarbeet	7%	25%
Sugarcane	26%	66%
Wheat	11%	30%

Table 9; IFPRI (2006)

These figures show that significant price increases may occur on the world markets in response to biofuel production.

3.1.4 Impact on cattle breeding in the USA

The ambitious biofuels programs are likely to trigger noteworthy increases in the prices of agricultural commodities. However, it should not be concluded too quickly to unanimously positive consequences for the whole agricultural sector: a sharp contrast could well emerge between grain producers and cattle breeders.

The new demand for corn energy uses competes with the traditional feed and food outlets. This new demand, which would trigger a price increase for corn, would lower the demand for corn coming from the breeding sector. However, ethanol production generates a co-product (30% of the dry matter): DDGS (Distiller's Dried Grain with Solubles) which is a protein-rich compound (25 to 27%) that can substitute for soycakes or corn in the ruminants' intake. DDGS are less suitable for hogs and poultry but they can partially substitute for soycake and corn by adding some amino-acids. 3/4 of DDGS produced by the ethanol industry will be used for cattle breeding, 10% will be exported and the remaining 15% will be directed to other uses. within the part used by breeding, 80% of DDGS will be used by beef (meat), 10% for dairy beef and only 5% for hogs and poultry.

3.1.5 Biofuel imports

The question of importing biofuels from countries whose production costs are cheaper will be very acute in the upcoming years in the EU and the US alike.

These imports would mainly come from Brazil[35] (which produces ethanol from sugar cane) and from Malaysia and Indonesia (for palm oil, which is esterified to give biodiesel). Note that the international trade of biofuels has always been very limited and that a necessary (but not sufficient) condition for its taking off would be a clarification of the legal statute of biofuels with respect to the WTO.[36] What is at stake in this problem is the extent to which domestic production of energy crops should be favored compared to imported biofuels.

[35] According to the report by the EU Commission (2006a), ethanol imports to the EU have added up to 2.5 millions hl in average during the period 2002-2004. Only 30% of the total volume has been traded under the MFN conditions, most imports benefit from tariff reductions under preferential agreements (ACP agreements, GSP, GSP+ and EBA).

[36] It is unclear whether biofuels are agricultural, environmental or energy products. For the time being, this question still needs to be addressed, as stated in a recent report by the International Policy Council (2006).

The expansion of sugar in Brazil is closely linked to the history of this country. Sugar was first produced in the Nordeste region, then the production was developed in the São Paulo region (where modern sugar refineries and distilleries have been built) and in the Center-West region. The increase in areas and yields have allowed a steady rise in production: from 24hl per hectare in the sixties to 66hl in 2004. Significant progress has also been accomplished on an energy basis, with an ever more efficent use of bagasse. Brazil is the first producer and exporter of sugar in the world, but the increased production and consumption of sugar lowers its export balance: half the sugar factories are now used to produce domestic ethanol. Sugar cane makes up 3/4 of the global sugar production, the remaining quarter being produced from sugar beet in temperate zones. The figures about ethanol in Brazil are impressive: production amounts to 154 millions hl (one third of global production, with an increase of 55% forecasted for 2010), 60% coming from the South-West and Center-West region, the remaining 40% being produced in the Nordeste region ; three millions cars are flex-fuel vehicles or work with 100% hydrous ethanol (and 16 millions run on fuel or a fuel-anhydrous ethanol blending) ; 320 factories process almost 400 millions tons of sugarcane annually. However, in spite of an annual 6%-increase in cane production, some authors remain skeptic as regards the Brazil's capacity to satisfy the additional demand in sugar and ethanol. The Proalcool plan decided in 1975 following the first oil shock had been initiated by the State which gave sizeable incentives (like, for example: subsidies for buying cars running solely on ethanol, obligation for the state-owned company Petrobras to buy a given quantity of ethanol, setting of the ethanol price below the gasoline price, etc.) to develop ethanol. However, this plan did not outlive the counter oil shock of 1986, which was followed by a surge in the sugar market at the beginning of the nineties: the sugar was a better outlet than ethanol. Moreover, the state did not want to bear the overcost of ethanol with respect to gasoline. Quite logically, the production of cars running solely on ethanol periclited until a complete halt in 1996. A new era in the development of ethanol was triggered in 2004 as flex-fuel vehicles were launched. These vehicles are partly subsidised by the state and make up 75% of the sales of new cars. The emergence of flex-fuel cars is a means to enable a long term development of biofuels in Brazil. Brazil is often touted as the future global supplier of ethanol. However, the perspective of a 5% use of ethanol in the total fuel consumption worldwide raises important issues in Brazil and appears as a threat to some authors. Sugar cane accounts today for 10% of the cultivated land (a little less than 6 millions hectares), but could well be extended on 90 millions additional hectares (in the Center-West region mainly). The most frequently heard objections to this possibility are: the intrusive character of this crop, its fragility in the face of large-scale cryptogamic and viral diseases and the fact that production is profitable only for big landowners. Moreover, a control of the agricultural production seems necessary (The firing of cane leaves before harvest leads to smoke clouds which are responsible for the formation of ozone). A solution would be an increased mechanization (where technically possible). The social effects of ethanol production have been positive (800 000 direct jobs have been created in the industry). However, the fate of the "boias frias", agricultural workers paid proportionally to the quantity of cane harvested and the downside consequences of monoculture on human nutrition are parameters to consider when reflecting on the public policy of ethanol production in Brazil.

Box 9: The situation in Brazil: ethanol production. This is a summary from an article by Bertrand, J.-P. et al., entitled "La politique brésilienne en matière de biocarburants : le pari sur l'éthanol", published in the Biofuel Survey under the supervision of Tréguer, D., Déméter 2008, 352 pp.

Biodiesel imports into the EU are subject to an *ad-valorem* duty of 6.5 %. Despite this low tariff, there is nearly no imports of biodiesel, mainly because biodiesel

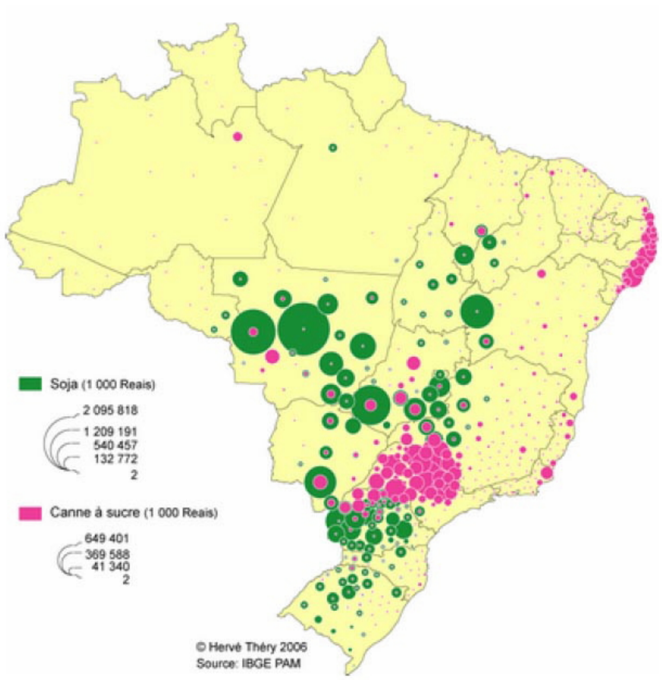

Fig. 3.4. Main feedstock for biofuels in Brazil: soybeans and sugar cane. Map created by Hervé Théry, published in Déméter 2008.

production outside the EU is very limited. Tariffs on vegetable oils are either nil or very low. There are some technical difficulties for using large quantities of soybean oil in biodiesel. However, low percentages of soy and palm oil can be combined with rapeseed oil without particular problems. As a result, one observes an increase in EU imports of palm oil, mainly from Malaysia. The ambitious incorporation targets set by the EU might require importing significant quantities of palm oil, not only for their use for biodiesel production but also because of substitution possibilities between the various vegetable oils in food uses.

As noted by the European Commission, "there is currently no specific customs classification for bioethanol for biofuel production" and "it is not possible to establish from trade data whether or not imported alcohol is used in the fuel ethanol sector in the EU" (Commission of the European Communities, 2006a). Despite this uncertainty, one can reasonably assume that the increase in EU imports of alcohol (from 1.45 million hectoliters in 1999-2001 to 2.56 million hectoliters in 2002-2004) is largely due to the ethanol demand. Thanks to the various preferential agreements in force in the EU, in particular the EU Generalized System of Preferences (GSP) for the Least Developing Countries (the "Everything But Arms" initiative), the GSP+ granted to 14 countries including all Latin American countries except Argentina, Brazil, Chili, Paraguay and Uruguay, and the Cotonou Agreement with 77 African, Caribbean and Pacific (ACP) States, large quantities of alcohol can enter into the EU at a zero or reduced tariff: EU imports of alcohol at a reduced or zero duty increased from 1.2 million hectoliters in 2002 to 2.0 million hectoliters in 2004. With the growing number of developing countries interested in accessing the EU market under the GSP+, it is expected that these favored imports will keep growing. Alcohol imports from major producers, in particular Brazil and the United States, face high Most Favored Nation (MFN) tariffs, that is 19.2€ per hectoliter on undenatured alcohol and 10.2€ per hectoliter on denatured alcohol. Despite this protection, EU imports from MFN suppliers are increasing (from 0.66 million hectoliters in 2002 to 1.1 million hectoliters in 2004).

The issue of allowing easier imports, in particular for ethanol, divides European countries. Some countries (Portugal and Sweden for example) are highly favorable to the idea arguing that the energy and greenhouse gas balances of Brazilian ethanol are far better than the ones of EU bioethanol produced from wheat or sugar beets. Other countries (in first place France and Germany) strongly oppose the idea: clearly, France and Germany play the biofuel card also with the view to supporting their own farmers.

3.2 Formalizing the link between biofuel and agricultural policies: a model.

As[37] pointed out in the studies presented in the first part of this chapter, subsidizing the biofuel industry raises the price of the agricultural feedstock. The increase in the

[37] This section is adapted from the first part of an article by J.-M. Bourgeon and D. Tréguer, entitled: "Killing Two Birds with One Stone: US and EU biofuel programs.

agricultural commodity prices raises the farmer revenue, and reduces the need for direct income support. Hence, for a given objective of agricultural income, the regulator is able to operate a partial substitution between direct agricultural income support and subsidies to the biofuel industry. Owing to the importance of the Common Agricultural Policy (CAP) in the EU budget,[38] the question of a partial substitution of biofuel subsidies for CAP payments could be on the EU political agenda very soon.

This section is related to the literature on the transfer efficiency of agricultural programs (Alston and Hurd, 1990 and Gardner, 1983), which notably considers the incidence of the opportunity cost of public funds in the relative efficiency of economic instruments aimed at supporting farmers incomes. Indeed, biofuel subsidies (and mandatory blending) could be considered a new element in the already wide range of instruments at the regulator's disposal.

We develop a model that disentangles the various effects that the support granted to biofuels may trigger. We show that without constraint on biofuel production (e.g. coming from security of energy supply concerns), the government may find it worthwhile to implement a biofuel program to diminish the social cost of the farm support program: indeed, it may be socially beneficial to implement such policies if costs of public funds are high. This result might explain why biofuel programs have been in place in the EU and the US for more than a decade. Considering the possibility of importing agricultural feedstock, the government may still take advantage of substitution between the farm support program and the biofuel subsidy policy.

[38] In 2007, it represents more than €40 billion, i.e. 37% of the EU budget, (European Commission, 2007).

This effect leads to a higher domestic price of the agricultural commodity than the world price, relatively low import levels, and the biofuels produced from imported agricultural feedstock benefiting from a lower subsidy than biofuels produced from domestic input. When the biofuel production constraint is binding, the optimal domestic production of feedstock exceeds the optimal (unconstrained) level of supply of agricultural raw product that prevails in autarky.

The section is organized as follows. First, our model is presented and the optimal production of energy crops is derived. Then, the import scenario is dealt with.[39]

3.2.1 The model

Consider an economy with an agricultural sector, a food sector and an energy sector. All agents in this economy are price-takers. The production cost of the agricultural product is affected by the farmers' environmental practices. Denote by $C(X, e)$ the cost function of the representative farm, where X is the production level and $e \in [0, e_M]$ is an environmental index (e.g. the polluting emission level), with $C_{Xe} < 0$. Hence, the more the farmer pollutes, the lower the marginal cost of production.[40] Both the food and energy industries use the agricultural feedstock in order to produce their own outputs (food products and biofuels, respectively). The total quantity of the agricultural product is thus split between the food (x_F) and energy (x_E) sectors: $X = x_F + x_E$. The production function of the representative firm in the food industry is denoted by $y_F = f_F(x_F)$ with $f_F' > 0$ and $f_F'' < 0$. The production function of

[39] All proofs are placed in the appendix.

[40] We also assume $C(X, e)$ convex: we have $C_{XX} > 0, C_{ee} > 0$ and $C_{XX}C_{ee} - C_{Xe}^2 > 0$.

the energy sector is $f_E(x_E) = \gamma x_E$, where $\gamma < 1$ is a positive parameter. Profit maximization of the representative farmer determines the inverse agricultural supply function, given by $C_X(X, e)$. Denote by $p_F(y_F)$ and p_E the prices for the food and the energy products. p_E is supposed unaffected by the production of biofuel and such that:

$$C_X(X, 0) - \gamma p_E > 0$$

i.e. the energy firm production cost is greater than its revenue, whatever environmental standard e. We shall first consider in the following that the government has decided to grant energy firms a per unit subsidy σ_E which allows biofuel firms to break even,[41] and then discuss mandatory blending.[42] As $C_{XX} > 0$, the subsidy should rise with the desired quantity of energy crops, as the price of the domestic crop becomes higher. Hence, the demand coming from the energy firms for the agricultural product is determined by the biofuel objective of the government. Total demand for the agricultural product is determined by the demand coming from the food industry and is deduced as follows. Solving the program of the representative firm of the food industry, given by:

$$\Pi_F \equiv \max_{x_F} p_F(y_F) f_F(x_F) - C_X(X, e) x_F, \tag{3.1}$$

[41] We assume that the energy firm has no private information: the regulator knows the firm's technology and cost function.

[42] We discuss the mandatory blending framework at the end of this section.Of course, other policies are possible, like, first of all, a Pigouvian tax on fossil fuels.

where $p_F(y_F)$ and $C_X(X, e)$ are considered as constant, the equilibrium condition on the input market leads to an optimal input demand x_F satisfying:

$$g(x_F, x_E, e) \equiv p_F(y_F) f_F'(x_F) - C_X(x_F + x_E, e) = 0, \tag{EC}$$

for all $x_E \geq 0$. For a given environmental index e, (EC) implicitly defines x_F as a function of x_E.

3.2.2 Optimal biofuel policy in autarky

The objective of the regulator is to maximize the sum of the surpluses of the different agents in the economy: farmer profits Π_A, food and energy industry profits, Π_F and Π_E, the consumer surplus CS,[43] and the taxpayer surplus T. It also takes account of a guaranteed income $\overline{\Pi}_A$ for farmers. Hence, the taxpayer must finance the biofuel program on the one hand and the direct payments to farmers on the other. The total cost of subsidizing the energy crops is given by $\gamma x_E \sigma_E$, while the parity income constraint leads to spending equal to $\overline{\Pi}_A - \Pi_A$. The total public spending is affected by $1 + \lambda$ in the Social Welfare Function (SWF), where λ is a positive parameter representing the social cost of public funds (see Fullerton, 1991 for a discussion on the value of λ). We thus have:

$$T = (1 + \lambda)[(C_X - \gamma p_E)x_E + \overline{\Pi}_A - \Pi_A].$$

The environmental effects of the agricultural production are summarized in an environmental damage function $D(e)$, with $D'(e) > 0$, i.e. the greater the farms' emis-

[43] CS is the Marshallian consumer surplus deriving from the consumption of food: $CS(x_F) = \int_0^{y_F(x_F)} p_F(y_F(x_F))dy_F$

sions, the larger the environmental damages. One of the regulator's tasks is to determine a socially desirable environmental standard $\bar{e}$ for agriculture. Of course the regulator also has to make sure that farmers do comply with the environmental guidelines. We first characterize the situation of costless enforcement implying $e = \bar{e}$, and discuss the enforcement problem in a specific section. Last, an environmental benefit stemming from the GHG mitigation effect of biofuels is also accounted for in the SWF: let $B(x_E)$ be this environmental benefit and assume that $B'(x_E) = q > 0$. As explained above, the profit of the biofuel industry Π_E is equal to zero. Absent any constraint on the biofuel production level, the government's program is given by:

$$\max_{x_E, x_F, \bar{e}} \{\overline{\Pi}_A + CS + \Pi_F - (1+\lambda)[(C_X - \gamma p_E)x_E + \overline{\Pi}_A - \Pi_A] + B - D : (EC)\} \quad (3.2)$$

International agreements or energy supply security concerns may oblige the agency to produce at least some given level Q of biofuel. This would introduce another constraint in program (3.2), given by: $x_E \geq Q/\gamma$. To simplify the presentation, we do not include this constraint in the government program, but we discuss the case of a binding biofuel production constraint in the following. Neglecting constant $\overline{\Pi}_A$, the Lagrangian of program (3.2) may be written as:

$$\mathcal{L} = CS + \Pi_F - (1+\lambda)[(C_X - \gamma p_E)x_E - \Pi_A] + B - D - \beta g(x_F, x_E, \bar{e})$$

where β is the Lagrange multiplier corresponding to the market equilibrium condition (EC). The optimal policy satisfies the following first-order conditions:

$$\frac{\partial \mathcal{L}}{\partial x_F} = \lambda x_F C_{XX} - \beta(\partial g/\partial x_F) = 0 \quad (3.3)$$

$$\frac{\partial \mathcal{L}}{\partial x_E} = \lambda x_F C_{XX} - (1+\lambda)[C_X - \gamma p_E] + q - \beta\left(\partial g/\partial x_E\right) \leq 0 \qquad (x_E^* \geq 0) \qquad (3.4)$$

and

$$\frac{\partial \mathcal{L}}{\partial \bar{e}} = \lambda x_F C_{Xe} - (1+\lambda)C_e - D' - \beta\left(\partial g/\partial e\right) = 0. \qquad (3.5)$$

Besides, we define the derivative of x_F with respect to x_E for a given environmental standard $\bar{e}$: $\frac{dx_F}{dx_E} = -\frac{\partial g/\partial x_E}{\partial g/\partial x_F}$.

The reader can easily verify that solving equations (3.3)-(3.5) for $\bar{e}, x_E$ and x_F leads to the following result:

Proposition 1 *The optimal policy $\bar{e}^*, x_E^*$ and x_F^* is implicitly defined by (EC),*

$$\lambda x_F C_{XX}\left[1 + \frac{dx_F}{dx_E}\right] - (1+\lambda)[C_X - \gamma p_E] + q \leq 0 \qquad (x_E^* \geq 0) \qquad (3.6)$$

and

$$\lambda x_F C_{XX}\left[1 + \frac{dx_F}{dx_E}\right] = \frac{C_{XX}}{C_{Xe}}\{(1+\lambda)C_e + D'\}. \qquad (3.7)$$

Proof: See the appendix.

To interpret (3.6), consider the case $\lambda = 0$. We would have

$$C_X(X, \bar{e}) - \gamma p_E = q$$

i.e., the Pigouvian rule that the optimal subsidy should equalize the marginal benefit of GHG mitigation. With $\lambda > 0$, a binding constraint (3.6) implies that the optimal subsidy for biofuels (which entails the shadow cost of public funds) exceeds the marginal benefit of GHG mitigation. More precisely, without any constraint on biofuel production, the regulator must choose a quantity of energy crops up to the point where the marginal social loss of subsidizing the biofuel sector equals the sum of the GHG positive externality and the marginal social gain of the transfer of revenue from the food sector to farmers. Indeed, the increase in the price of the agricultural raw product makes it possible to diminish the direct payment to farmers: a marginal increase dx_E in biofuel demand transfers a revenue equal to $-(d/dx_E)\left[CS + \Pi_F\right] = x_F C_{XX}(X, \bar{e}) dX/dx_E$ from the food sector (the food industry and consumers) to farmers. This transfer allows the government to reduce the extent of the farm support program, hence the corresponding tax distortions caused in the rest of the economy. For high levels of x_F, the total subsidy outlay may in fact diminish: indeed, for a given environmental standard $\bar{e}$, we have

$$\frac{d}{dx_E}\left[(C_X(X,\bar{e}) - \gamma p_E)x_E + \overline{\Pi}_A - \Pi_A\right] = C_X(X,\bar{e})\left[\frac{C_X(X,\bar{e}) - \gamma p_E}{C_X(X,\bar{e})} - \frac{dX}{dx_E}\frac{x_F/X}{\epsilon(X,\bar{e})}\right]$$

where $\epsilon(X, \bar{e})$ is the price elasticity of the agricultural crop supply, given by $\epsilon(X, \bar{e}) = C_X(X, \bar{e})/[X C_{XX}(X, \bar{e})]$. Hence, the variation in total public spending may be negative provided that the elasticity of agricultural supply is low and x_F/X, the share of food sector demand in the total demand for feedstock, is large. A sufficient condition to have a strictly positive level of biofuel at the optimum of the government's program is that (3.6) being strictly positive when no biofuel program is in place and all the agricultural crops are used as an input for the food industry (i.e., $x_E = 0$ and $x_F = X_0$, the feedstock production level bought by the food sector when no biofuel is produced):

$$\lambda X_0 C_{XX}(X_0, \bar{e})(dX/dx_E)|_{x_E=0} - (1+\lambda)[C_X(X_0, \bar{e}) - \gamma p_E] + q > 0$$

Leaving aside GHG mitigation concerns (i.e. even with $q = 0$), we have $x_E^* > 0$ if $\lambda \geq \lambda_s(\bar{e})$ defined by:

$$\lambda_s(\bar{e}) = \frac{C_X(X_0, \bar{e}) - \gamma p_E}{X_0 C_{XX}(X_0, \bar{e})(dX/dx_E)|_{x_E=0} - (C_X(X_0, \bar{e}) - \gamma p_E)}$$

Consequently, when the shadow cost of public funds is large, the regulator should implement a biofuel program for the reason that transferring income from the food sector to farmers allows it to reduce the social cost of the farmer income support policy. In order to give a hint of the value of λ_s, consider rapeseed production in the EU-15. With a price elasticity of the agricultural crop supply equal to 0.28 (see the FAPRI elasticity database), $\gamma p_E / C(X_0, \bar{e}) = 0.5$ and a 10% decrease in the consumption of rapeseed by the food industry, i.e. $(dx_F/dx_E)|_{x_E=0} = -0.1$, we have $\lambda_s = 0.18$. This value is below the lower boundary of the range of λ given in the literature (0.2 to 0.6). Therefore, a strictly positive quantity of biodiesel ought to be produced in the EU-15, on purely redistributive grounds.

Equation (3.7) allows us to characterize the optimal standard policy. The last term of (3.7) corresponds to the marginal social surplus of agricultural production under standard $\bar{e}^*$: $D'(\bar{e}^*)$ is the marginal damage and $-C_e(X^*, \bar{e}^*)$ the marginal reduction in production cost which corresponds to a social benefit $-(1+\lambda)C_e(X^*, \bar{e}^*)$ in public funds.[44] The Pigouvian rule calls for an environmental standard that nullifies this surplus. The first term of (3.7) corresponds to the marginal social surplus of biofuel production, with the marginal social loss of subsidizing the biofuel sector given

[44] The term C_{XX}/C_{Xe} corresponds to the (opposite of the) "marginal rate of substitution" between the agricultural feedstock and the environmental standard at a given price of the agricultural product: we have $(d\bar{e}/dX)|_{C_X=cst} = -C_{XX}/C_{Xe}$.

by $(1+\lambda)[C_X(X^*, \bar{e}^*) - \gamma p_E]$ and the value of the social benefit of GHG mitigation given by q. The Pigovian level also requires that this marginal surplus is nill. However, we know from (3.6) that this marginal surplus is equal to the marginal social gain of the transfer of revenue from the food sector to farmers, which is positive whenever $\lambda > 0$. With a positive social cost of public funds, as C_{XX}/C_{Xe} is negative, the marginal damage of agricultural production is lower than its marginal social benefit, implying that the optimal standard $\bar{e}^*$ is lower than the Pigouvian level. This can be easily understood: by setting a stringent environmental standard, the regulator increases the marginal cost of production (we have $C_{Xe} < 0$), hence the price of the agricultural feedstock which reinforces the substitution effect between the biofuel subsidy policy and the farm support program.

Let us now consider the case of a policy constrained to reach a given level of biofuel production Q. We then have $x_E = Q/\gamma$ and the first-order conditions with respect to x_F and $\bar{e}$ lead to the optimal policy $(x_F^c, \bar{e}^c)$ that satisfies:

$$\lambda x_F^c C_{Xe}(X^c, \bar{e}^c) \left.\frac{dX}{dx_E}\right|_{X=X^c} = (1+\lambda)C_e(X^c, \bar{e}^c) + D'(\bar{e}^c) \tag{3.8}$$

where $X^c = Q/\gamma + x_F^c$. Again (3.8) implies that $\bar{e}^c$ is lower than the Pigouvian level $\bar{e}^P$ corresponding to the production level X^c implied by Q.

3.2.3 Mandatory blending

The main economic instruments to promote biofuels are subsidies. However, governments tend to rely more and more upon a second type of instrument which does not harm public finances: mandatory blending. In this situation, the consumer is compelled to use a given amount of biofuels $\gamma_E x_E$. We still assume that the biofuel firm satisfies the demand and that the government reimburses its production cost. As a result, the consumer faces a higher price for gasoline: indeed, the price of the "aggregate gasoline" (i.e. fossil fuel mixed with a given proportion of biofuel) is $p_G = p_E + (x_E/y_E)(C_X - p_E\gamma_E)$. Denoting by $CS(y_F, y_G)$ the consumer's surplus corresponding to a consumption bundle (y_F, y_G) of food products and gasoline, the regulator's program is written as follows:

$$\max_{x_E, x_F, \bar{e}} \{\overline{\Pi}_A + CS(y_F, y_G) + \Pi_F - (1+\lambda)[\overline{\Pi}_A - \Pi_A] + B - D : (EC)\} \tag{3.9}$$

Neglecting the constant $\overline{\Pi}_A$, the Lagrangian of program (3.9) may be written as:

$$\mathcal{L}^{MB} = CS(y_F, y_G) + \Pi_F + (1+\lambda)\Pi_A + B - D - \beta g(x_F, x_E, \bar{e})$$

where β is the multiplier corresponding to the market equilibrium condition (EC). The optimal policy satisfies the following first-order conditions:

$$\frac{\partial \mathcal{L}^{MB}}{\partial x_F} = \lambda X C_{XX} - \beta(\partial g/\partial x_F) = 0 \tag{3.10}$$

$$\frac{\partial \mathcal{L}^{MB}}{\partial x_E} = \lambda X C_{XX} - [C_X - \gamma p_E] + q - \beta\left(\partial g/\partial x_E\right) \leq 0 \qquad (\widetilde{x}_E^* \geq 0) \tag{3.11}$$

and

$$\frac{\partial \mathcal{L}^{MB}}{\partial \bar{e}} = \lambda X C_{Xe} - (1+\lambda)C_e - D'(\bar{e}) - \beta\left(\partial g/\partial e\right) = 0. \tag{3.12}$$

Using (EC), (3.10) and (3.11) lead to the following condition:

$$\lambda X C_{XX}(X, \bar{e})\frac{dX}{dx_E} - [C_X(X, \bar{e}) - \gamma p_E] + q \leq 0 \qquad (x_E \geq 0). \tag{3.13}$$

Rearranging terms, we obtain the following result:

Proposition 2 *If λ is large, the optimal policy with mandatory blending is implicitly defined by (EC) and*

$$[C_X - \gamma p_E] - q = \lambda X C_{XX} \frac{dX}{dx_E} = \frac{C_{XX}}{C_{Xe}} \{(1+\lambda) C_e + D'\} \tag{3.14}$$

Compared to the optimal subsidy policy x_E^*, x_F^* and $\bar{e}^*$, we have $x_E^{MB} > x_E^*$ and $\bar{e}^{MB} < \bar{e}^*$.

Proof: See the appendix.

The level of biofuels produced in the case of a mandatory blending framework is greater than with a subsidy. This result is hardly surprising, as the consumer surplus is affected by a weight equal to 1 in the Social Welfare Function, while the taxpayer surplus is weighted $1+\lambda$.

As concerns environmental standard $\bar{e}$, the mandatory blending framework imposes a more stringent level: as the taxpayer only pays for the decoupled payment directed at the farmers, the price increase of the agricultural raw material can be pushed a step further.

3.2.4 Importation of energy crops

The results of the previous section are limited to a quantity produced domestically. However, buying energy crops on the world market could prove less expensive for society. We now consider that the energy firm may also buy its raw material on the world market. Let X_E be the total quantity of energy crops, $X_E = x_E + x_I$, where x_E is the domestic energy crop and x_I the imported one, bought on the world market at price $\overline{w}$ from a perfectly elastic supply. The subsidies awarded by the regulator to the biofuel sector are $\sigma_E = C_X(X, \bar{e})/\gamma - p_E$ for domestic energy crops, and $\sigma_I = \overline{w}/\gamma - p_E$ for imported energy crops. The biofuel subsidy is thus given by $S = \gamma(\sigma_E x_E + \sigma_I x_I)$. With no biofuel production constraint, the regulator's program can be written as:

$$\max_{x_E, x_I, x_F, \bar{e}} \{\overline{\Pi}_A + CS + \Pi_F - (1+\lambda)(S + \overline{\Pi}_A - \Pi_A) + B - D : (EC)\} \tag{3.15}$$

Denoting by $\hat{x}_E, \hat{x}_I, \hat{x}_F$ and $\hat{e}$ the optimal regulator choices, the biofuel feedstocks levels must satisfy the following conditions:

$$\lambda x_F C_{XX}(\hat{X}, \hat{e}) \frac{d\hat{X}}{dx_E} - (1+\lambda)\{C_X(\hat{X}, \hat{e}) - \gamma p_E\} + q \leq 0 \qquad (\hat{x}_E \geq 0) \tag{3.16}$$

and

$$-(1+\lambda)(\overline{w} - \gamma p_E) + q \leq 0 \qquad (\hat{x}_I \geq 0). \tag{3.17}$$

where $\hat{X} = \hat{x}_E + \hat{x}_F$. The latter condition states that (absent any constraint on the biofuel production), the optimal imported crop level equates the marginal social cost of subsidizing the biofuel industry with the marginal environmental benefit of biofuel. If q is large, it is optimal to import as much agricultural commodity as possible because of the positive GHG mitigation effects. We assumed that it is not the case and consequently that we have $\hat{x}_I = 0$ when the government has no minimal biofuel production objective. Compared to (3.17), condition (3.16) entails the marginal social gain of the transfer of revenue from the food sector to the farmers, which eases the condition for a positive level of domestic biofuel crops. As (3.16) is similar to (3.6), the resulting demand levels are the same as those obtained in the case of a closed economy: we have $\hat{x}_E = x_E^*$, $\hat{x}_F = x_F^*$ (and $\hat{x}_I = 0$).

If the country faces a minimal biofuel production level $Q > \gamma x_E^*$, energy crops produced domestically exceed level x_E^*. Indeed, substituting $Q/\gamma - \hat{x}_E$ for $\hat{x}_I$ in program (3.15) and maximizing in $\hat{x}_E$ and $\hat{x}_F$, we arrive at the following condition:

$$\lambda x_F C_{XX}(\hat{X}, \hat{e}) dX/dx_E - (1+\lambda)[C_X(\hat{X}, \hat{e}) - \overline{w}] = 0 \tag{3.18}$$

which implicitly defines $\hat{x}_E$. Plugging $x_E = \hat{x}_E$ into (3.16) and using (3.18) to substitute for the first term, we get:

$$(1+\lambda)[C_X(\hat{X}, \hat{e}) - \overline{w}] - (1+\lambda)[C_X(\hat{X}, \hat{e}) - \gamma p_E] + q = -(1+\lambda)(\overline{w} - \gamma p_E) + q < 0$$

which implies that $\hat{x}_E > x_E^*$. Hence, taking imports into account, we have the following results:

Proposition 3 *When the government can import the agricultural feedstock at price $\overline{w} > \gamma p_E - q/(1+\lambda)$:*

- *With no constraint on the biofuel production level, it is optimal to produce energy crops if λ is large. All the agricultural feedstock is produced domestically and we have $\hat{x}_E = x_E^*$, $\hat{x}_F = x_F^*$ and $\hat{x}_I = 0$.*

- *If the government has a biofuel production objective $Q > \gamma x_E^*$, it is optimal to produce energy crops domestically at level $\hat{x}_E > x_E^*$ implicitly defined by (3.18). Importations of raw materials are given by $\hat{x}_I = Q/\gamma - \hat{x}_E$. The internal price of the agricultural feedstock verifies $C_X(\hat{X}, \hat{e}) > \bar{w}$ leading to subsidies $\sigma_E > \sigma_I$.*

Conclusion

The first part of this chapter has shown that biofuel production will have deep and long lasting consequences on agricultural markets, albeit all the complexities and the uncertainties of biofuel programs. These high levels of agricultural prices drastically change the context in which a reform of the agricultural policy may take place. The model presented here strives to anticipate the likely reform of the Common Agricultural Policy in the context of an important biofuel production. First, we have shown that biofuel programs may allow the regulator to operate a partial substitution between decoupled payments and the support for biofuels. This substitution is detrimental to the food industries (and to the consumers). However, when the social cost of public funds is high, the regulator should finance a biofuel program because of its redistributive property. Of course, this result rests on the existence of sufficiently high distortions in the tax system. The positive environmental externalities attributed to the substitution of biofuels for fossil fuels tend to push the optimal biofuel quantity a step further. We also developed a simple framework which took account of the possibility of imports: thanks to the economy of public funds permitted by biofuels, the optimal level of energy crops produced domestically is set at a level where the interior price exceeds the world price for energy crops. The conclusions drawn in the case of a biofuel program financed through subsidies can also be made when biofuels are promoted thanks to a mandatory blending scheme. The optimal level of biofuels that ought to be produced is even higher in that case. We have tried to keep our model as simple as possible. However, many refinements could be implemented. First, we have considered that the subsidies were fine-tuned. This assumption could be criticized, as there are informational asymmetries between the regulator and the biofuel firms. In the mandatory blending framework, such informational asymmetries are not relevant but informational rents could well be replaced by monopolistic rents for biofuel producers. For instance, the major biodiesel firm in France covers more than 75% of the market. We have also assumed a perfectly competitive agro-food sector. Relaxing this assumption may well lead to very stringent conditions for a socially valuable subsidy substitution effect between the farm support and the biofuel program.

Even if such a drastic reform (which can be considered to a certain extent as a re-coupling of the support to agriculture) seems at odds with the recent evolution of the CAP (which was characterized by ever more decoupled payments to agriculture), the importance of biofuel production within European agriculture and its impact on agricultural prices calls for a thorough re-thinking of the way agriculture is supported in the EU. Indeed, it seems quite unlikely that farmers will continue to enjoy a double support from taxpayers. A certain form of substitution between support to agriculture and to biofuels seems unavoidable.

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Appendix

Proof of proposition 1

From (EC), we have $\partial g/\partial x_E = -C_{XX}$ and $\partial g/\partial e = -C_{Xe}$. Rearranging terms of (3.3) yields:

$$\beta = \lambda x_F C_{XX}/(\partial g/\partial x_F) = -\lambda x_F(\partial g/\partial x_E)/(\partial g/\partial x_F) = \lambda x_F dx_F/dx_E$$

Plugging into (3.4) and (3.5) gives:

$$\frac{\partial \mathcal{L}}{\partial x_E} = \lambda x_F C_{XX} \frac{dX}{dx_E} - (1+\lambda)[C_X - \gamma p_E] + q \leq 0 \qquad (x_E^* \geq 0)$$

and

$$\frac{\partial \mathcal{L}}{\partial \bar{e}} = \lambda x_F \frac{dX}{dx_E} C_{Xe} - (1+\lambda) C_e - D' = 0 \tag{3.19}$$

Rearranging terms gives (3.7).

Proof of proposition 2

Denoting by $S^* \equiv (x_E^*, x_F^*, \bar{e}^*)$ the optimal subsidy policy, we have, using (3.10), (3.11) and (3.6):

$$\begin{aligned} \left.\frac{\partial \mathcal{L}^{MB}}{\partial x_E}\right|_{S^*} &= [\lambda X C_{XX} dX/dx_E - (C_X - \gamma p_E) + q]|_{S^*} \\ &= [\lambda x_E C_{XX} dX/dx_E + C_X - \gamma p_E]|_{S^*} > 0 \end{aligned}$$

hence $x_E^+ > x_E^*$.

Similarly, using using (3.10), (3.12), (3.3)and (3.5):

$$\begin{aligned} \left.\frac{\partial \mathcal{L}^{MB}}{\partial \bar{e}}\right|_{S^*} &= [\lambda X C_{Xe} dX/dx_E - (1+\lambda) C_e - D'(\bar{e})]|_{S^*} \\ &= [\lambda X C_{Xe} dX/dx_E - \lambda x_F C_{Xe} dX/dx_E]|_{S^*} \\ &= [\lambda x_E C_{Xe} dX/dx_E]|_{S^*} < 0 \end{aligned}$$

hence $\bar{e}^+ < \bar{e}^*$.

Proof of proposition 3

Substituting $Q/\gamma - x_E$ for x_I in the government program leads to the following Lagrangian (neglecting the constants):

$$\mathcal{L} = CS + \Pi_F - (1+\lambda)[(C_X - \bar{w})x_E - \Pi_A] - D(\bar{e}) - \beta g(x_F, x_E, \bar{e})$$

The first-order conditions are:

$$\frac{\partial \mathcal{L}}{\partial x_F} = \lambda x_F C_{XX} - \beta(\partial g/\partial x_F) = 0$$

$$\frac{\partial \mathcal{L}}{\partial x_E} = \lambda x_F C_{XX} - (1+\lambda)[C_X - \bar{w}] - \beta\left(\partial g/\partial x_E\right) = 0$$

and

$$\frac{\partial \mathcal{L}}{\partial \bar{e}} = \lambda x_F C_{Xe} - (1+\lambda)C_e - D'(\hat{e}) - \beta\left(\partial g/\partial e\right) = 0$$

and give:

$$\frac{\partial \mathcal{L}}{\partial x_E} = \lambda x_F C_{XX}\frac{dX}{dx_E} - (1+\lambda)[C_X - \bar{w}] = 0$$

and

$$\frac{\partial \mathcal{L}}{\partial \bar{e}} = \lambda x_F C_{Xe}\frac{dX}{dx_E} - (1+\lambda)C_e - D'(\hat{e}) = 0$$

deriving the following condition:

$$\lambda x_F C_{XX}\frac{dX}{dx_E} = (1+\lambda)[C_X - \overline{w}] = \frac{C_{XX}}{C_{Xe}}\{(1+\lambda)C_e + D'(\hat{e})\}$$

Chapter 4
Enforcing environmental policies in agriculture: what do biofuels change?

Introduction

The deep changes triggered by the emergence of biofuels raise important questions about their impact on the environment. The effects of biofuels on environmental policies are double-edged. On the one hand, biofuels are one of the main features of the greenhouse gases (GHG) mitigation policies in the transportation sector. On the other hand, the sizeable production of energy crops will have major implications on environmental policies for the agricultural sector. Hence, the environmental externalities are positive for the GHG emissions, but negative for the agricultural production. We choose to leave aside the positive externalities linked to the use of biofuels as a substitute for fossil fuels[45] to concentrate on the issue of energy crops and the environment. There is an essential contradiction between setting a prominent objective for biofuel production that will lead (through higher prices) to higher yields and thus to an intensification of the agricultural production, and the adoption of sound agricultural practices.

[45] A growing number of articles suggest that these externalities may indeed turn out to be negative. See, e.g., Fargione *et al.*, 2008.

In the EU, the large-scale production of biofuels raises very important questions with respect to the evolution of the CAP concerning the enforcement of environmental provisions. The latest reforms of the CAP (2002's Mid-Term Reform notably) had introduced the concept of cross-compliance, which linked decoupled payments to the respect of 19 Directives. Biofuel production (although not formally part of the CAP) puts the whole cross-compliance scheme at risk. Indeed, with the high levels of price (partially caused by the decision to produce large quantities of biofuels), the incentive to exceed environmental standards increases. Hence, the regulator needs to update its enforcement policy. This chapter intends to deal with two questions of interest with respect to the setting of environmental standards in agriculture:

First, environmental provisions ought to be correctly enforced in order to be respected. This means that the regulator ought to set environmental standards and implement an inspection scheme (fine + probability of detection) in order to control emission levels.

Secondly, the new situation of high agricultural prices (partly due to biofuel production) requires a complete re-shaping of environmental policies directed to agriculture. Environmental provisions had been designed in the context of low agricultural prices. With high commodity prices, the regulator ought to enforce a stringent environmental policy in a context in which market parameters stimulate an increased use of polluting agricultural inputs.

In the United States, the large-scale production of corn used to make ethanol sparks off environmental concerns. Considering various scenarios of mandatory blending levels, Marshall and Greenhalgh (2006) establish the environmental damages stemming from corn production. The study points to the risks of local pollution by phosphates and nitrates, as well as soil erosion problems. In addition, the authors note that the high levels of prices on the soybean and corn markets might push some farmers to opt out of the Conservation Reserve Program (CRP).[46]

Annual production, ethanol	**Billion gallons**	**5**	**7.5 (current RFS)**	**10**	**12.5**	**15**
		Baseline	Percent change from baseline			
Fertilizers	Million tons	9	2.1	4.2	6.1	8.4
N leaking to water	Million tons	5.2	1.5	2.9	4.2	5.6
P leaking to water	Million tons	0.6	1.8	3.2	4.4	6
Erosion	Million tons	1,776	1.5	2.8	4	5.3
GHG emitted by agriculture	Million tons	87	1.9	3.8	5.6	7.7

Table 1 ; Marshall and Greenhalgh (2006)

The study by Marshall and Greenhalgh stresses the fact that the increased rate of nutrient and soil loss is by far larger than the rate at which supplementary land is brought into production. Farmers respond to the new market conditions (stimulated by the ethanol market) by giving up environmental-friendly rotations and tillage in favor of agricultural practices that are more nitrogen-intensive. The authors also point to a slight decline in acreage managed using low-till or no-till techniques (which are

[46] This program has been set up mainly for soil conservation purposes. Project are ranked following an Environmental Benefit Index, and the farmers who are chosen agree to crop native grasses (no cash crop) in exchange of payments from the State. The contracts usually run for 10 to 15 years.

beneficial for the environment). Some problems of eutrophication of rivers, streams and lakes could be observed, as well as reduced fish habitat and oxygen-depleted zones in coastal waters. Their report concludes by underscoring the necessity of diversifying the agricultural raw material used to produce ethanol, mainly by speeding up the shift to the second generation of biofuels, produced from a ligno-cellulosic raw material.

More recently, a report from the National Academy of Science underlined the very negative consequences in the Mexico Gulf linked to the increased production of corn (for ethanol) in the Midwest (National Academy of Sciences, 2008). Besides, the consequences of the sizeable ethanol production for the CRP scheme is studied by Secchi and Babcock (2008). They come up to the conclusion that environmentally sensitive land will be cropped again owing to the high prices for corn, and that very high spending levels would be necessary to maintain those lands within the CRP.

Although the environmental downside effects of biofuel production are more documented in the US than in the EU for the time being, the focus of this chapter will be set on the EU situation.[47] The latest reforms of the CAP have evolved towards ever closer links between agriculture and the environment. As the agricultural payments became more and more decoupled from production, the decoupled payments became correlatively more and more coupled with the respect of environmental provisions. The growing importance of biofuel production within the European agriculture calls for a rebuilding of environmental policies directed to agriculture. One of the so-

[47] The European Environmental Agency has begun to raise concerns about the environmental risks linked to the production of first-generation biofuel in the EU. They recently stood up against the objective of the European Commission, imposing a 10% blending of biofuels by 2020.

lutions put forward by some stakeholders (among which the EU Commission) is to set up a certification framework, as it has been achieved in forest management. This certification would especially apply for the production of palm oil in Malaysia and Indonesia (IHT, 2006) and should be enforced in a non-discriminatory way for both European and imported biofuels (EU Commission, 2006, and WWF, 2006). However, it seems that certification, as presented by the European Commission, is a mere redefinition of the environmental cross-compliance. Besides, certification is subject to controversies since it could be used by protectionist countries as a non-tariff barrier to trade. The implementation of biofuel certification would also stir up some practical problems.[48]

Hence, the problem of biofuel certification is closely linked to the agricultural stage of biofuel production. Sound agricultural techniques seem to be a necessary condition for the certification of the whole biofuel production chain. Therefore, the problem faced by biofuel certification boils down in great part to the respect of the already-existing environmental provisions embodied in the agricultural policies. Thus, biofuel certification will require correctly enforced environmental policies. To be effective, environment policies cannot only be enacted by a given legislative body: they are respected only to the extent that they are correctly enforced. Seemingly adequate environmental regulations can completely fail if their enforcement is not properly designed.

[48] For instance, the control of the whole energy crops production, within and outside the borders of the EU will prove difficult. As these controls have a cost, it is necessary to find the optimal trade-off between control and pollution.

As stressed by Bontems and Rotillon (2003), an efficient control policy is not a mere definition of the right level of tax or norm to abide by. The conventional rule which states that pollution should be reduced to the point where the marginal damage and the marginal cost of pollution reduction are equal does not apply any more if enforcing the rule is costly. Cost of pollution should be added up with the marginal cost of control. This ultimately reduces the level of environmental standards that must be imposed to farmers. Following Becker (1968), an enormous body of literature has been developed around the "economics of crime", with a straightforward transposition to the enforcement problem in environmental policies. Some major contributions of this branch of literature will be presented.

In order to put into perspective the links between biofuels and agri-environmental policies, the future of the CAP ought to be addressed: if the scenario of a decrease in the level of decoupled payments materializes, the penalties in the framework of cross-compliance (a fraction of the Single Farm Payment) will lose their role as a credible deterrent. We do not intend to suggest that the next reform of the CAP will necessarily consist in a strong substitution of biofuel support for CAP payments. However, in the same way as we tried to predict what could unfold as regards the surpluses of the various agents in the previous chapter, we reflect on the likely impacts that such an agricultural policy shift would have environment-wise. For this purpose, the model developed in the previous chapter is extended to the question of the enforcement of environmental provisions. In the previous chapter, we have shown that because of the social cost of public funds, the optimal standard is stricter than the

Pigouvian level. Indeed, by setting a stringent environmental standard, the regulator increases the marginal production cost, hence the price of the agricultural feedstock, which reinforces the substitution effect between the biofuel subsidy policy and the farm support program. However, this standard is less stringent taking account of the cost of enforcing the environmental policy. We analyze the effects of a monitoring cost on the biofuel production (assuming that production levels are not constrained) and on the agricultural environmental standard assuming that the government may inflict two types of monetary sanctions: fines and cross-compliance provisions. We compare these two policies and show that for a large level of biofuels, cross compliance provisions are less effective than fines.

Hence, the structure of this chapter is the following: first, we detail the environmental provisions contained in the CAP: cross-compliance and agri-environmental schemes principally, and we point to the main flaws concerning the enforcement of these policies. Then, we make a brief review of the literature concerning the monitoring and enforcement of environmental policies. Finally, the core of the chapter will be presented. It deals with a model linking the issues of the CAP likely evolution stemming from the higher production of biofuels, and the related problems that emerge about the enforcement of the environmental regulation.

4.1 Environmental policies within the CAP: the enforcement problem

Before addressing specific environmental issues linked to biofuel production, the general framework of environmental provisions in the CAP is presented. Even if biofuel production is not directly tied up to the CAP, the new environmental issues that will crop up in the upcoming years might well be linked to the agricultural phase of their production. The sustainability of biofuels hinges upon the fulfillment of strong environmental standards as regards the production of energy crops. Hence, the various environmental schemes embodied in the CAP are first reviewed. We present 3 aspects of the links between the CAP and the environment: cross-compliance, agri-environmental schemes and the nitrates Directive.

4.1.1 Cross-compliance

The agenda 2000 reform of the CAP established the separation between the two pillars of the CAP: the market and income policy ("first pillar") and the sustainable development of rural areas ("second pillar"). Moreover, the Agenda 2000 reform initiated the principle following which farmers ought to abide by environmental protection requirements (i.e. the so-called "cross-compliance" provisions) in order to benefit from market support schemes. The 2003 CAP reform went a step further, making cross-compliance mandatory.

With the enactment of the 2003 reform, all farmers receiving direct payments must respect mandatory cross-compliance provisions. Farmers ought to fulfill the requirements of 19 European legislative acts applying directly at the farm level in the domains of environment, public and animal health, pesticides and animal welfare. Farmers will face partial or total withdrawal of their Single Farm Payment (SFP) in case of non-compliance. Moreover, beneficiaries of direct payments have to keep land in good agricultural and environmental conditions. MS are given some leeway to define precisely these conditions. However, standards related to soil protection, maintainance of soil organic matter and soil structure, and conservation of habitats and landscape must be set by the MS. Finally, MS must also ascertain that there is no major loss in their total permanent pasture area. If need there be, they should prohibit its conversion to arable land (EU Commission, DG Agriculture website).

4.1.2 Monitoring and enforcement of Agri-environmental measures

Alongside cross-compliance provisions stand the agri-environmental measures, which go beyond the good farming practices (GFP). These agri-environmental schemes were first introduced at the end of the 1980s as an instrument to support specific farming practices to protect the environment and maintain the countryside. The 1992 CAP reform made the implementation of agri-environmental measures compulsory for MS. Agri-environmental measures consist in the reimbursement of the additional costs faced by farmers who commit (for a minimal 5-years' period) to adopt strong environmental farming techniques. Such environmental measures are, e.g. the extensification of farming, conversion to organic farming, conservation of high-value habitats and the associated biodiversity, etc. The first period of implementation covered the period 1993-1999. In 1998, the European Parliament and the Council made a joint statement in which the integration of environmental concerns into the CAP was identified as a priority.[49] In response to these orientations, the Commission decided that the program for the period 2000-2006 would include "strengthened agri-environment measures as compulsory elements" of rural development programs (RDP). Indeed, agri-environmental measures are the only mandatory elements for the MS to include in their RDPs. Agri-environment measures are co-financed by the EU, with a 75% contribution in Objective 1 (least developed) areas and up to 50% in other areas. This co-financing was revised upwards in 2004 with up to 85% for Objective 1 areas and up to 60% in other areas. The average agri-environment subsidy in the EU in 2001 amounted to 89€ per hectare. However, there is a great heterogeneity in the payment rates (depending on the sub-measure and the MS). In aggregate terms, agri-environmental support appears to be the largest rural development measure with 13.5 billions euros of EU co-financing which have been handed out for the period 2000-2006: this amounts to 27% of all rural development expenditure (Court of Auditors, 2005).

[49] Decision No 2179/98/EC of the European Parliament and of the Council of 24 September 1998 on the review of the European Community program of policy and action in relation to the environment and sustainable development.

Enforcement seems however to be Achilles' heel of environmental policies related to agriculture in the EU.[50] The EU Court of Auditors issued a report on the implementation of the first program of agri-environmental measures (1993 to 1999).[51] Its main conclusion dealt with the non-verifiability of some agri-environmental measures, such as the reduction of fertiliser usage: "The problem is known to the Commission's own checkers, but the Commission continues to adopt such measures". Likewise, the Commission realized two detailed evaluations of the implementation of agri-environmental programs for the period 1993-1999.[52] These evaluations stressed the fact that the measures which requested a reduction in the use of inputs by a certain amount or which demanded not to exceed a given quantity of fertilizer per hectare were tricky to check since soil analyses could not reliably assess the respect of the limits. Moreover, the reports noted that the inspection of the farm's book are not sufficient to identify errors or irregularities.

In the control of the agri-environmental measures, much emphasis is put on the self-declarations of the beneficiaries. However, if the enforcement procedure does not incorporate a properly designed monitoring scheme with adapted penalties in case of infringement, the environmental policy might well fail. The Court of auditors noted that: "Checks on sub-measures inspected in France for example, rely to a large ex-

[50] Although we focus on the EU framework, it should however be noted that the conservation programs in the US face the same enforcement problems. Indeed, a recent report by the Government Accounting Office (2003) states that the farm bill's cross-compliance provisions have been inconsistent due to an inadequate enforcement of the policy.

[51] Court of auditors, Special Report No 14/2000 "Greening the CAP".

[52] Commission Report to the Council and European Parliament on the application of Council Regulation (EEC) No 2078/92, COM(97) and DG VI Working Document VI/7655/98: State of application of Regulation (EEC) No 2078/92: Evaluation of agri-environment programmes.

tent on the veracity of the declaration made by the beneficiaries and, in particular, on the reliability of the parcel and grazing logbooks. In these documents, the farmer himself enters applications of fertilisers and phytosanitary products, planting, mowing and harvesting activities, and grazing periods. The checkers are not obliged to go beyond simply verifying that the data have been entered in these logbooks". A Commission inspection report concluded that this type of check could not be considered sufficient and had to be supplemented by other types of check. Indeed, the Commission's guidelines recommend complementing the checks on the information recorded by the beneficiary by other checks focusing, for example, on yield, invoices or soil and plant analyses. Taking account of the numerous flaws which characterize the enforcement of the agri-environmental schemes, and given the non-negligible amounts spent in such environmental undertakings, the EU Commission stressed the fact that, "if a measure cannot be adequatly checked, it should not be the subject of public payment". However, the Court of Auditors noted that this rule is respected to a limited extent.

4.1.3 The nitrates Directive: an enforcement problem

Water pollution is one of the most prominent environmental problems addressed to the EU. Since 1973, more than 20 Directives concerning water quality have been enacted. Dating back from 1991, the nitrates Directive[53] is one of the most important measures in that respect. It principally deals with the monitoring of water quality in relation

[53] Council Directive 91/676/EEC of 12th December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources.

to agriculture and the designation of so-called "nitrate vulnerable zones" for which specific measures ought to be taken. Most notably, the Directive sets an upper limit for nitrogen coming from livestock manure in these zones: 170kg N/ha/year. This Directive had a dual objective: to reduce water pollution by nitrates from agricultural sources and to prevent further pollution. Before to be put into action, the Directive first needs to be transposed into the national laws of the MS. This first legislative undertaking proved quite difficult: 5 years after the Directives' enactment, some MS had still not transposed the Directive. Only a minority of MS have fully implemented the Directive and the Commission began disciplinary procedures for the MS which fail to properly apply the directive.

In spite of all the environmental provisions embodied in the nitrates Directive, its implementation has failed in many MS. This is largely due to numerous problems in the Directive's enforcement. First, the Directive is a European legislative text that first needs to be translated into the national laws. Thereafter, the implementation hinges upon the decision at a decentralised level, e.g. the *départements* in France. Hence, the enforcement of the directive proves highly heterogenous.[54] Indeed, as noted by Greer (2005), this example illustrates the fact that the EU lacks a properly developed administrative apparatus and relies on member states to implement policy decisions. Partly for this reason the EU is often said to suffer from an implementation deficit in which it struggles to ensure compliance with its directives

[54] The most laxist *départements* with respect to the provisions contained in the Action Plans were also those where the nitrates problem was the most acute, i.e. in Brittany. (Tréguer, D. Report on the enforcement of the nitrates Directive, 2002).

and regulations: effective policy enforcement is highly dependent on national level institutions.

4.2 Enforcing environmental policies in agriculture: a review of literature

As pointed out in the preceding section, the success of an environmental policy hinges upon the effectiveness of the associated control scheme. Indeed, to enforce a demanding policy it is necessary for the State to control farms frequently and to be able to inflict sizeable penalties. Owing to the technical difficulties linked to a permanent control of polluting emissions in many cases, fraud may concern a non-negligible proportion of farmers if the inspection mechanisms and penalties are no sufficient deterrents. However, these instruments have to be carefully determined. Monetary penalties are transfers which do not imply costs for society, whereas a credible level of control does imply such costs. In order to minimize the costs of these controls, it therefore seems necessary that their frequency be as low as possible and that the penalty be as high as possible. As intuitive as these prescriptions appear to be, the penalties applied are hardly ever maximal, since all agents do not have the same payment capacities and since a certain progressiveness in the penalty scheme should be applied so that penalties reflect the importance of the fraud (the punishment must fit the crime.) Otherwise, any polluter having decided to pollute would pollute at the maximal level. An efficient environmental policy should comprise an ex-post control scheme of the agents' decisions with adapted sanctions in cases of non-compliance.

Inflicting sanctions can also imply expenses for the regulator and more generally, for society: the trade-off between the frequency of controls and the importance of the sanction is determined by their respective costs. For instance, stiffer sanctions incur costs (prosecution, loss of revenue by farmers facing mandatory production disruptions) that are not counterbalanced by gains for other parties, contrary to monetary penalties.

4.2.1 Modelling the polluting farm

Assume that the polluting emissions are entirely controlled by the farm, i.e. the presence of pollution can only stem from a deliberate and rational intention to pollute. The question which we will focus on deals with the incentives given by the different economic instruments (standards, taxes or emission permits) to evade the regulation, for a given auditing policy, i.e. a system of penalties and probabilities of being controlled. The profit of the farm derived from emitting a quantity e of pollution: $\pi(e)$ stems froms the following maximization program:[55]

$$\pi(e) = \underset{q}{max}\ pq - C(q, e) \tag{4.20}$$

where p is the price of good q and $C(q, e)$ is the cost function, characterized by properties to ensure the concavity of the program, i.e. C convex in each of its

[55] This model is adapted from Bontems and Rotillon (2000)

arguments and globally convex ($C_{qq} > 0, C_{ee} > 0$ and $C_{qq}C_{ee} - C_{qe}^2 > 0$). Let e^a be the level of emissions announced to the regulator, e its true level of pollution and s the ongoing standard. Assuming that the farmer is risk-neutral, his utility is given by the following expression:

$$U(e, e^a) = \pi(e) - \Phi(e^a - s) - p(e - e^a)[\Psi(e - e^a) + \Phi(e - s) - \Phi(e^a - s)] \quad (4.21)$$

$\Phi(.)$ is the penalty schedule to be paid by the farm when it announces that the standard will not be met, while $\Psi(.)$ is the penalty triggered when a fraud has been discovered. $p(.)$ is the probability of detection, which depends upon the intensity of the violation of the announced level of pollution. The above formulation is very general and may be adapted to any economic instrument used to regulate pollution: a standard, a tax or an emission trading system.

The farm has to choose its optimal announcement e^a to the regulator, and its true level of pollution e. After optimizing with respect to each choice variable and upon rearranging terms, the optimal trade-off is given by:

$$\pi'(e) = p(e - e^a)\Phi'(e - s) + [1 - p(e - e^a)]\Phi'(e^a - s) \quad (4.22)$$

Hence, the optimal level of pollution is chosen such that the marginal profit derived from pollution equals the sum of marginal expected penalties for a violation of the standard, with respect to the real and to the declared level of pollution.

4.2.2 The Becker single-act framework

Becker founded the economics of crime with his seminal article published in 1968. His approach can be summed up in the following way: inspections being costly, while fines are monetary transfers without deadweight losses, the regulator ought to substitute increased fine payments for the intensity of control. Thus, the level of the fine must be raised up to the initial wealth of the firm. Let us present the framework developed by Becker more in depth. Assume that farms may commit a damaging act to the environment, like for example an overuse of pesticides. The resulting effect of this damaging act is the same whatever the farm and has a monetary value D. The private benefit that the farms get from polluting varies across the farms. Let $\pi(\theta)$ be this benefit, distributed on $[\underline{\theta}, \overline{\theta}]$, with cumulative distribution function F and density f. For simplicity reasons, we assume that $\pi(\theta) = \theta$. However, we also suppose that the regulator does not have the auditing rights to assess the benefit that the farm extracts from polluting. Moreover, let μ, c, P and w_0 respectively be the probability of control, the cost of control, the penalty decided by the regulator and the maximal amount the government can charge the farmer due to the limited liability constraint.

The program of the regulator is the following:

$$\begin{array}{l} \underset{\mu,P}{max} \displaystyle\int_{\mu P}^{\overline{\theta}} [\theta - D] f(\theta) d\theta - c\mu \\ s.t.\ P \leq \overline{P} \end{array} \tag{4.23}$$

The constraint of the program must be binding, i.e. the regulator inflicts the maximum possible penalty (the maximum the governement can charge), $\overline{P} = w_0$. Assume it is not the case, i.e. the optimal expected fine is given by $K = \mu^* P^*$, with

$P^* < \overline{P}$, which yields a welfare $W(\mu^*, P^*) = \int_{\mu P}^{\overline{\theta}} [\theta - D] f(\theta) d\theta - c\mu^*$. Observe that for the same expected penalty, it could be possible to reduce the intensity of control: indeed, we have $\mu' = K/\overline{P} < \mu^* = K/P^*$and the policy $(\mu', \overline{P})$ yields a welfare $W(\mu', \overline{P}) = W(\mu^*, P^*) + c[\mu^* - \mu'] > W(\mu^*, P^*)$, hence a contradiction. Thus, the optimal policy is to inflict a penalty up to the maximal amount that the government can charge. Maximization with respect to μ gives the optimal monitoring effort, μ^{**}, which is such that:

$$\mu^{**}\overline{P} - D = -c/f(\mu^{**}\overline{P}) \tag{4.24}$$

Hence, the expected penalty is smaller than the damage, while efficiency requires to (implicitely) allow farmers with $\theta > D$ to pollute. As monitoring farms is costly, the regulator will allow farms whose private benefit is lower than the environmental damage to pollute. In Becker's framework, the penalties should always be set at their maximal level. However, this might not always be optimal, as any farm which has decided to pollute will therefore have an incentive to pollute at the maximal level.

4.2.3 Departure from the Becker Single-act model

As pointed out by Cohen (1999), many developments in the economics of crime literature have consisted in criticizing or refining Becker's seminal article (1968), like Townsend (1979), Polinsky and Shavell (1984) and Border and Sobel (1987).

While Becker's approach allows to take the heterogeneity of the sector into account, it is too simple to give sensible policy requirements in most real-life contexts, particularly when the damage to society depends on the intensity of the individual's deeds. This becomes particularly important when considering the provision of environmental goods. Mookherjee and Png (1994) shows that "punishment must fit the crime". Compared to Becker, their analysis allows to determine the social norm, i.e. the polluting intensity thereshold that triggers punishment. Any intensity below this level is thus allowed. Above this level, violators have to pay according to their self-indulgences.

4.3 Biofuels and cross-compliance: a model

This section[56] addresses the issue of the enforcement of environmental policies in agriculture, in the context of an increased production of energy crops. We will deal with the limits of the existing instrument (environmental cross-compliance) in the new biofuel framework. The single farm payment (which decoupled support from production) was introduced with the CAP mid-term reform of 2002-2003, together with provisions for cross-compliance. As far as feedstock production is concerned, the main environmental issues deal with nitrates and pesticides. The nitrates directive has already been presented earlier in this chapter. As for pesticides, their use is regulated by EU directives aiming at controlling the way pesticides get market access and the level of residues in food. Moreover, the water framework Directive of 2000 imposes

[56] This section is adapted from the second part of the article by J.-M. Bourgeon and D. Tréguer, entitled: "Killing Two Birds with One Stone: US and EU biofuel programs.

measures to reduce significantly discharges and losses of dangerous substances, in order to protect surface water.

The aim of decoupled payments is therefore twofold: on the one hand, it guarantees a parity income to farmers; on the other hand, it intends to guarantee that agricultural production takes place in a framework which is compatible with sound environmental practices. The decoupled payment might be partially or totally withdrawn from the farmer, should some infringement be discovered when controls are carried out. Two effects are likely to occur with the development of biofuels. On the one hand, the incentives to evade the environmental cross-compliance policy[57] will increase with the high level of feedstock prices. On the other hand, as mentioned in the previous chapter, the regulator may be tempted to diminish the payment to farmers (since farmers' income will rise), which corresponds to a decrease in the maximal penalty at his disposal. Hence, if the subsidies (and other supports) for biofuels were to partially substitute for decoupled farm payments, cross-compliance would lose some of its justification, credibility and efficiency. It is central to find what kind of protection could be set up in order to temper the evolution of the production of energy crops towards more intensive practices. We might question the incentive strength of the possibility to reduce or withdraw the decoupled payment in case of infringement as this payment is downsized.

[57] Full granting of the single farm payment to farmers is linked to compliance with statutory environmental, food safety, animal and plant health, and animal welfare standards. Land must also be kept in "good agricultural and environmental condition."In the case of non-respect of these measures, direct payments can be reduced or withheld. In the case of negligence, the overall payment to be withheld is set at a maximum of 5%, or 15% for repeated offences. For intentional non-compliance, the fine is not less than 20%, and may go as far as total exclusion from receipt of payment for one or more years.

4.3.1 The model

In this section, we discuss the problem of defining the environmental standard considering the enforcement issue of such a policy. Indeed, to enforce a demanding policy it is necessary for the State to inspect farms frequently and to be able to inflict sizeable penalties. We shall analyze this problem in a framework similar to Malik (1992), considering that inspecting farms is costly and that the government inflicts penalties that depend on the extent of the infringement. We analyze the two cases of an exogenous maximal penalty, and of a maximal penalty which corresponds to the farmer's decoupled payment, as is the case in the EU. We do not consider importations in this section.

Assume that whenever a farmer has chosen an emission level e that exceeds the standard $\bar{e}$, the agency is able to inflict a penalty that depends on the extent of the farmer's infringement, $e - \bar{e}$, and more precisely that the corresponding penalty is a fraction $f(e - \bar{e}) \in [0, 1]$ of a maximal penalty Ψ. The function $f(\cdot)$ is exogenously given (by an independent legislative body) and is assumed increasing and convex in $e - \bar{e}$, with $f(0) = 0$. The maximum penalty can either be a given amount $\bar{P}$ (also determined by an independent legislative body), or the decoupled payment that the farmer should receive in case of compliance, i.e. $\overline{\Pi}_A - \Pi_A(X, \bar{e})$. The latter case corresponds to the current framework chosen by the EU to enforce environmental policies in agriculture. Let k be the probability of being inspected, and μk the corresponding cost.

Denoting by w the price of the agricultural product, the representative farmer solves the following maximization program:

$$\max_{X,e} wX - C(X,e) - kf(e-\bar{e})\Psi$$

Maximization with respect to e gives an optimal level e^* which satisfies:

$$-C_e(X,e^*) - kf'(e^*-\bar{e})\Psi \leqslant 0 \tag{4.25}$$

i.e., the marginal cost reduction from pollution must be lower than (or equal) to the marginal expected penalty. Since there is no social benefit associated to the payment of fines,[58] we have $e^* = \bar{e}$ at the optimum of the government's program: no fine is paid in equilibrium. Moreover, as inspecting farms is costly, this condition is binding at the optimum of the agency program, i.e. we have:

$$-C_e(X,\bar{e}) - kf'(0)\Psi = 0 \tag{IC}$$

Taking the same core model as in Chapter 3, the agency simultaneously chooses the optimal level of control, the environmental standard and the scope of the biofuel program by maximizing the following program:

$$\max_{x_E,x_F,k,\bar{e}} \{\overline{\Pi}_A + CS + \Pi_F - (1+\lambda)[(C_X - \gamma p_E)x_E + \overline{\Pi}_A - \Pi_A + \mu k] + B - D : (IC),(EC)\}$$

Assuming an interior solution for the biofuel level, we have the following result:[59]

Proposition 4 *Taking account of the cost of inspection, the optimal (unconstrained) policies verify:*

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[58] Since we assume that public funds are costly, it could be interesting to raise money by inflicting fines. However, we rule out such a possibility since this would entail administrative as well as psychological costs.

[59] The proofs have been placed in the appendix to this chapter.

- A) In the case of a fixed maximal penalty ($\Psi = \bar{P}$),

$$(1+\lambda)[C_X - \gamma p_E] - q = \left[\lambda x_F C_{XX} - (1+\lambda)\mu k \frac{C_{Xe}}{C_e}\right] \frac{dX}{dx_E}$$
$$= -\frac{C_{XX}}{C_{Xe}} \left\{-D' - (1+\lambda)C_e - (1+\lambda)\mu k(C_{ee} - C_{eX}^2/C_{XX})/C_e\right\}$$

  assuming that the optimal policy $\bar{e}^f, x_E^f$ and x_F^f is such that $x_E^f > 0$.

- B) In the case of cross-compliance provisions ($\Psi = \overline{\Pi}_A - \Pi_A$),

$$(1+\lambda)[C_X - \gamma p_E] - q = \left[\lambda x_F C_{XX} - (1+\lambda)\mu k \frac{C_{Xe} - kf'(0)XC_{XX}}{C_e}\right] \frac{dX}{dx_E}$$
$$= -\frac{C_{XX}}{C_{Xe}} \left\{-D' - (1+\lambda)C_e - (1+\lambda)\mu k(C_{ee} - C_{eX}^2/C_{XX} + kf'(0)C_e)/C_e\right\}$$

  assuming that the optimal policy $\bar{e}^{cc}, x_E^{cc}$ and x_F^{cc} is such that $x_E^{cc} > 0$.

- We have $\bar{e}^f > \bar{e}^*$ and $x_E^{cc} < x_E^f < x_E^*$.

Compared to the costless enforcement policy $(x_E^*, \bar{e}^*)$, the cost of inspections introduces distortions in the agency's trade-offs, resulting in lower biofuel production levels and less stringent environmental standards. However, the distortion on the production side is lower with a fixed penalty than under cross-compliance provisions. Not surprisingly, the emissions level taking the cost of inspection into account is higher than when enforcement is costless. Indeed, allowing for more emissions reduces the farmer's gain from exceeding the environmental standard, which in turn allows the frequency of inspection to be diminished.

Consider now that the government is constrained by a biofuel objective Q and suppose it desires to enforce a given environmental standard $\bar{e}$. Denote by $X(Q, \bar{e})$

the agricultural production implied by the equilibrium condition (EC). The corresponding monitoring efforts under fixed penalty, k^f, and cross-compliance, k^{cc}, can be deduced from (IC). We have:

$$k^f > k^{cc} \iff \Pi_A(X(Q,\bar{e}),\bar{e}) < \overline{\Pi}_A - \bar{P},$$

and the same condition holds for the welfare levels reached under the two alternative governemental policies. Hence, cross-compliance may prove the most efficient policy if $\bar{P}$ is low compared to the parity income and if agricultural production $X(Q,\bar{e})$ is low. However, for large biofuel objectives, the government is more likely to choose a fixed penalty policy. Indeed, $e^{cc}(Q)$, the optimal environmental standard under cross-compliance given the biofuel objective Q, increases implying that $\Pi_A(X(Q,e^{cc}(Q)),e^{cc}(Q))$ also strictly increases with Q. Hence, for any objective greater than $Q_s \equiv \inf\{Q \geq 0 : \Pi_A(X(Q,e^{cc}(Q)),e^{cc}(Q)) \geq \overline{\Pi}_A - \bar{P}\}$, the government is able to implement the optimal environmental standard of the cross-compliance policy with a fixed maximal penalty policy and to reduce its monitoring effort and thus the cost of the enforcement policy.

Conclusion

This chapter has been dedicated to the environmental consequences of biofuel programs in the agricutural production process. Before addressing the specificities linked to the outbreak of biofuels in the environmental policies, a review of the existing environmental policies directed to agriculture has been conducted, while underlying the enforcement problems which characterize these policies. Most notably, the agri-environmental schemes have been found to lack the proper inspection schemes in order to be correctly implemented. As noted by the Court of Auditors: "The Commission, Council and Parliament should consider how the principle should be put into practice in respect of proposals for agri-environmental expenditure in the 2007 to 2013 planning period, taking into account, on the one hand, the risk of non-compliance and, on the other hand, the potential benefits of this type of expenditure". This trade-off should be closely considered when setting up an environmental policy. A large body of literature has been expanding to help regulators enforcing their environmental policies. The level of the fines as well as the probability of controls ought to be correctly tailored in order to design an efficient policy of control. Taking the environmental policy enforcement problem into account, the monitoring cost on the one hand and the incentive constraints on the other hand changes the optimal energy crop quantity and the optimal environmental standard obtained in the previous chapter. Besides, we may note that one way to avoid inflating the cost of environmental controls consists in taxing the polluting inputs. This taxation will induce farmers to adopt sounder agricultural practices.

Finally, it seems that the present framework of environmental provisions directed to agriculture needs a complete re-shaping. The new context of high commodity prices gives incentives to produce using high levels of polluting inputs. Should the level of decoupled payments decrease in the forthcoming reforms of the CAP, the threat of losing part of this decoupled payment will not be enough to deter farmers from exceeding the environmental standard, as the incentive to breach the environmental policy increases. Therefore, this chapter has shown that in such a context, the regulator must resort to monetary penalties which are exogeneously determined (they have no link with the decoupled payment levels).

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Appendix

Proof of proposition 4 A)

Neglecting constant $\overline{\Pi}_A$, the Lagrangian of the governments' program may be written as:

$$\begin{aligned}\mathcal{L}^f &= CS + \Pi_F - (1+\lambda)[(C_X - \gamma p_E)x_E - \Pi_A + k\mu] + B(x_E) - D(\bar{e}) - \beta g \\ &\quad -\xi[C_e + kf'(0)\Psi]\end{aligned}$$

where β and ξ are the multipliers corresponding to (EC) and (IC). In the case of a fixed maximum penalty, we have:

$$\frac{\partial \mathcal{L}^f}{\partial x_F} = \lambda x_F C_{XX} - \beta(\partial g/\partial x_F) - \xi C_{eX} = 0 \tag{4.26}$$

$$\frac{\partial \mathcal{L}^f}{\partial x_E} = \lambda x_F C_{XX} - (1+\lambda)[C_X - \gamma p_E] + q - \beta\,(\partial g/\partial x_E) - \xi C_{eX} \leq 0 \qquad (x_E^f \geq 0) \tag{4.27}$$

$$\frac{\partial \mathcal{L}^f}{\partial \bar{e}} = \lambda x_F C_{Xe} - (1+\lambda)C_e - D'(\bar{e}) - \beta\,(\partial g/\partial e) - \xi C_{ee} = 0. \tag{4.28}$$

$$\frac{\partial \mathcal{L}^f}{\partial k} = -(1+\lambda)\mu - \xi f'(0)\bar{P} = 0. \tag{4.29}$$

Using (EC), (4.26) and (4.27) lead to:

$$\frac{\partial \mathcal{L}^f}{\partial x_E} = [\lambda x_F C_{XX} - \xi C_{eX}]\frac{dX}{dx_E} - (1+\lambda)[C_X - \gamma p_E] + q \leq 0 \qquad (x_E^f \geq 0)$$

while (4.29) and (IC) give:

$$\xi = -(1+\lambda)\mu/[f'(0)\bar{P}] = (1+\lambda)\mu k/C_e$$

Consequently, we have:

$$\frac{\partial \mathcal{L}^f}{\partial x_E} = \left[\lambda x_F C_{XX} - (1+\lambda)\mu k \frac{C_{eX}}{C_e}\right] \frac{dX}{dx_E} - (1+\lambda)[C_X - \gamma p_E] + q \leq 0 \qquad (x_E^f \geq 0)$$

Similar computations give

$$\frac{\partial \mathcal{L}^f}{\partial \bar{e}} = \lambda x_F C_{Xe} - (1+\lambda)C_e - D'(\bar{e}) - [\lambda x_F C_{XX} - \xi C_{eX}] \frac{\partial g/\partial e}{\partial g/\partial x_F} - \xi C_{ee}$$

Using $\partial g/\partial e = -C_{Xe}$ and $\partial g/\partial x_E = -C_{XX}$ we get:

$$\begin{aligned}
\frac{\partial \mathcal{L}^f}{\partial \bar{e}} &= \lambda x_F C_{Xe} - (1+\lambda)C_e - D'(\bar{e}) - [\lambda x_F C_{eX} - \xi \frac{C_{eX}^2}{C_{XX}}] \frac{\partial g/\partial x_E}{\partial g/\partial x_F} - \xi C_{ee} \\
&= \left[\lambda x_F C_{Xe} - \xi \frac{C_{eX}^2}{C_{XX}}\right] \frac{dX}{dx_E} - (1+\lambda)C_e - D'(\bar{e}) + \xi \left[\frac{C_{eX}^2}{C_{XX}} - C_{ee}\right] \\
&= \frac{C_{Xe}}{C_{XX}} \left[\lambda x_F C_{XX} - (1+\lambda)\mu k \frac{C_{Xe}}{C_e}\right] \frac{dX}{dx_E} - (1+\lambda)C_e - D'(\bar{e}) \\
&\quad -(1+\lambda)\frac{\mu k}{C_e}\left[C_{ee} - \frac{C_{eX}^2}{C_{XX}}\right]
\end{aligned}$$

Denoting by $S^* \equiv (x_E^*, x_F^*, \bar{e}^*)$ the solution of program (3.2), we have:

$$\left.\frac{\partial \mathcal{L}^f}{\partial x_E}\right|_{S^*} = -(1+\lambda)\mu k \frac{C_{eX}(X^*, \bar{e}^*)}{C_e(X^*, \bar{e}^*)} \left.\frac{dX}{dx_E}\right|_{S^*} < 0$$

and

$$\begin{aligned}
\left.\frac{\partial \mathcal{L}^f}{\partial \bar{e}}\right|_{S^*} &= -\frac{(1+\lambda)\mu k}{C_e(X^*, \bar{e}^*)} \left.\left[\frac{C_{Xe}^2}{C_{XX}} \frac{dX}{dx_E} + C_{ee} - \frac{C_{eX}^2}{C_{XX}}\right]\right|_{S^*} \\
&= -\frac{(1+\lambda)\mu k}{C_e(X^*, \bar{e}^*)} \left.\left[\frac{C_{Xe}^2}{C_{XX}} \frac{dx_F}{dx_E} + C_{ee}\right]\right|_{S^*}
\end{aligned}$$

where:

$$\frac{C_{Xe}^2}{C_{XX}} \frac{dx_F}{dx_E} + C_{ee} > C_{ee} - \frac{C_{Xe}^2}{C_{XX}} > 0$$

and $C_e < 0$, implying:

$$\left.\frac{\partial \mathcal{L}^f}{\partial \bar{e}}\right|_{S^*} > 0$$

As $\mathcal{L}^f$ is concave, we thus have $\bar{e}^* < \bar{e}^f$ and $x_E^* > x_E^f$.

Proof of Proposition 4 B)

In the case of a cross-compliance policy, we have $-\xi[C_e(X,\bar{e}) + kf'(0)(\bar{\Pi}_A - \Pi_A)]$ as the last term of the Lagrangian.

$$\frac{\partial \mathcal{L}^{cc}}{\partial x_F} = \lambda x_F C_{XX} - \beta(\partial g/\partial x_F) - \xi[C_{eX} - kf'(0)XC_{XX}] = 0 \tag{4.30}$$

$$\frac{\partial \mathcal{L}^{cc}}{\partial x_E} = \lambda x_F C_{XX} - (1+\lambda)[C_X - \gamma p_E] + q - \beta\,(\partial g/\partial x_E) - \xi[C_{eX} - kf'(0)XC_{XX}] \leq 0 \qquad (x_E^f \geq 0) \tag{4.31}$$

$$\frac{\partial \mathcal{L}^{cc}}{\partial \bar{e}} = \lambda x_F C_{Xe} - (1+\lambda)C_e - D'(\bar{e}) - \beta\,(\partial g/\partial e) - \xi[C_{ee} - kf'(0)(XC_{eX} - C_e)] = 0. \tag{4.32}$$

$$\frac{\partial \mathcal{L}^{cc}}{\partial k} = -(1+\lambda)\mu - \xi f'(0)(\bar{\Pi}_A - \Pi_A) = 0. \tag{4.33}$$

Condition (4.30) gives:

$$\beta = \frac{\lambda x_F C_{XX} - \xi[C_{eX} - kf'(0)XC_{XX}]}{\partial g/\partial x_F}$$

while (4.33) and (IC) give:

$$\xi = -(1+\lambda)\mu/[f'(0)(\bar{\Pi}_A - \Pi_A)] = (1+\lambda)\mu k/C_e(X,\bar{e})$$

Consequently, we have:

$$\frac{\partial \mathcal{L}^{cc}}{\partial x_E} = \left[\lambda x_F C_{XX} - (1+\lambda)\mu k \frac{C_{eX} - kf'(0)XC_{XX}}{C_e}\right]\frac{dX}{dx_E} - (1+\lambda)[C_X - \gamma p_E] + q \leq 0 \qquad (x_E^f \geq 0)$$

Similar computations give:

$$\begin{aligned}\frac{\partial \mathcal{L}^{cc}}{\partial \bar{e}} &= \lambda x_F C_{Xe} - (1+\lambda)C_e - D'(\bar{e}) - [\lambda x_F C_{XX} - \xi(C_{eX} - kf'(0)XC_{XX})]\frac{\partial g/\partial e}{\partial g/\partial x_F} \\ &\quad -\xi[C_{ee} - kf'(0)(XC_{eX} - C_e)]\end{aligned}$$

Using $\partial g/\partial e = -C_{Xe}$ and $\partial g/\partial x_E = -C_{XX}$ we get:

$$\begin{aligned}\frac{\partial \mathcal{L}^{cc}}{\partial \bar{e}} &= \lambda x_F C_{Xe} - (1+\lambda)C_e - D'(\bar{e}) - C_{eX}\left[\lambda x_F - \xi\left(\frac{C_{eX}}{C_{XX}} - kf'(0)X\right)\right]\frac{\partial g/\partial x_E}{\partial g/\partial x_F} \\ &\quad -\xi[C_{ee} - kf'(0)(XC_{eX} - C_e)] \\ &= C_{Xe}\left[\lambda x_F - \xi\left(\frac{C_{eX}}{C_{XX}} - kf'(0)X\right)\right]\frac{dX}{dx_E} - (1+\lambda)C_e - D'(\bar{e}) \\ &\quad +\xi\left[\frac{C_{eX}^2}{C_{XX}} - kf'(0)XC_{Xe} - C_{ee} + kf'(0)(XC_{eX} - C_e)\right] \\ &= \frac{C_{Xe}}{C_{XX}}\left[\lambda x_F C_{XX} - (1+\lambda)\frac{\mu k}{C_e}\left(C_{eX} - kf'(0)XC_{XX}\right)\right]\frac{dX}{dx_E} \\ &\quad -(1+\lambda)C_e - D'(\bar{e}) + (1+\lambda)\frac{\mu k}{C_e}\left[\frac{C_{eX}^2}{C_{XX}} - C_{ee} - kf'(0)C_e\right]\end{aligned}$$

which gives the result.

Denoting by $S^f \equiv (x_E^f, x_F^f, \bar{e}^f)$, we have

$$\left.\frac{\partial \mathcal{L}^{cc}}{\partial x_E}\right|_{S^f} = (1+\lambda)\mu k^2 f'(0)X\frac{C_{XX}(X^f, \bar{e}^f)}{C_e(X^f, \bar{e}^f)}\left.\frac{dX}{dx_E}\right|_{S^f} < 0$$

hence $x_E^f > x_E^{cc}$. We also have:

$$\left.\frac{\partial \mathcal{L}^{cc}}{\partial \bar{e}}\right|_{S^f} = (1+\lambda)\frac{\mu k^2 f'(0)}{C_e(X^f, \bar{e}^f)}\left.\left[XC_{Xe}\frac{dX}{dx_E} - C_e\right]\right|_{S^f}$$

which is ambiguous.

Part III Common Agency: a new framework for agriculture regulation

The environmental provisions that had been implemented in the successive CAP reforms took place in a context of low agricultural prices, which made the environmental reforms more acceptable to farmers, who highly depended on CAP payments. However, biofuel policies have dramatically changed the framework of agricultural production by triggering price increases in agricultural markets. Abiding by environmental regulation seems now far more costly, as high commodity prices push farmers towards high production levels.

Of course, such a tension between environmental and production objectives has always existed. However, with the emergence of biofuels (and the price hikes that they trigger off), the opposition between these two objectives is reinforced. Hence, this part aims at formalizing agriculture's dilemma between high production levels and the respect of stringent environmental provisions linked to the CAP.

The previous part has studied the welfare consequences of biofuel production on the present CAP, with the agricultural sector modelled using a representative producer. This type of analysis allows to derive the relative efficiencies of different economic instruments used to reach an agricultural policy objective (see, e.g. Wallace, 1962, Gardner, 1983 or Alston and Hurd, 1990). However, the questions of the agricultural sector's heterogeneity and the informational asymmetries that exist between farmers and the regulator cannot be tackled by such modelling frameworks. The answer to such limitations in the traditional welfare analysis consists in applying Contract Theory to agricultural policies. Analyses by Lewis, Feenstra and Ware (1989), Chambers (1992) or Bourgeon and Chambers (2000) have followed this trail.

The last two chapters of the dissertation are built around the framework of Common Agency, a new branch of Contract Theory. This theory extends the Principal-Agent model to the presence of n principals (most often, n=*2).* It[60] appears to be a well-suited theoretical framework to study agriculture's dilemma for producing two types of goods like environmental (effort for reducing the use of polluting inputs) and "classical" agricultural goods. Contrary to the previous part, we explicitely model the heterogeneity of the farmers (linked to different technical abilities), which must be taken into account by the regulator, who is moreover in a position of informational asymmetry with the agents it regulates. In the presence of two principals, the difficulty of dealing with the informational asymmetry is reinforced by the competition exerted by the other principal. The question of interest is thus to assess the consequences of the competition between the two principals on the allocations levels. Common Agency will be presented in *Chapter 5.*

[60] The Common Agency adds a very important feature with respect to the traditional principal-agent relationship: the competition between the two principals in their contractual offer. Therefore, when offering her contract to the agent, the principal cannot only consider the agent's strategic behavior in revealing his information to her, she must also take into consideration the way the other principal's contract will affect the agent's information revelation to her.

Chapter 6 strives to model the regulation of the two types of goods produced by agriculture: an environmental good and a "classical" agricultural commodity. More generally, there is a tension between the stringent environmental objectives that the EU entities (most often the Commission) wish to promote and the opposition of the MS willing to unleash the production capacities of their agricultural sector. Hence, *Chapter 6* addresses the issue of regulation in the EU context, i.e. with a competition between the supranational regulator (the EU Commission) and the national regulator (a Member State). More precisely, the regulation which is considered gives the leadership for imposing its environmental regulation to the EU. This regulation framework fits well into the setting up of the Common Agricultural Policy's successive reforms, in which environment has been gaining pre-eminence over time.

While *Chapter 5* sets out the general framework of Common Agency applied to agriculture, *Chapter 6* focuses on the competition between regulators at the EU and national levels, in the case where the former is in a Stackelberg leader position. Biofuels are not the central subject of this part, however, they are responsible for the high tension between production and environmental objectives.

Chapter 5
Common Agency in agriculture

Introduction

This chapter aims at introducing the instruments of Common Agency in an agricultural framework. It paves the way for the next chapter, dealing with the separation of regulatory powers within the EU, for which the tools of Common Agency are extensively used. Common Agency adds a very important feature to the traditional principal-agent relationship: the competition between two principals in their contractual offers. Therefore, when offering her contract to the agent, one principal cannot only consider the agent's strategic behavior in revealing his information to her, she must also take into consideration the way the other principal's contract will affect the agent's information revelation to her.[61]

The term "Common Agency" was coined by Bernheim and Whinston (1986).[62] Two seminals papers due to Stole (1991) and Martimort (1992) investigate Common Agency under adverse selection. While ignoring each other's work at the time of the writing of their respective articles, they reached similar conclusions in the case of *intrinsic* Common Agency, i.e. when the agent can only accept both contractual offers from the principals or elect his outside opportunity. In the other family of Common Agency models, the agent can choose to contract with one or both principals or

[61] The female pronouns will refer to the principals, while the male pronouns will designate the agent.

[62] While their article deals with Common Agency under moral hazard, this chapter will be restricted to Common Agency under adverse selection.

neither of them if his outside opportunity is more appealing. These situations are referred to as *delegated Common Agency,* since the existence of the Common Agency is delegated by the choice of the agent, who prefers to contract with both principals rather than to choose the exclusive dealing outcome. This type of Common Agency framework is developed in Martimort and Stole (2003). While the first resolution of Common Agency problems[63] was built upon a very complex adaptation of the Revelation Principle (with an extension of the interval of types in order to avoid profitable deviations by the principals) as well as modified versions of the Taxation Principle (with an extension of the quantities that can be chosen by the agent), Martimort and Stole (2002) developed a new algorithm: "The Delegation Principle", which simplifies Common Agency problems. The contractual externalities between the two principals can either be indirect (they only interact through the agent's utility function, the cross-derivative of which is non-zero), or direct (the principal compete on the same output market, on which they sell goods that have been produced by the common agent), as in Martimort and Stole (2004). While these articles considered agents with continuously distributed efficiency parameters, Martimort and Stole (2002) developed a discrete model. More recently, Calzolari (2007) developed a model of a multinational firm in a Common Agency framework.

The following settings will be presented in this chapter. First, the perfect information framework will be dealt with, then we will develop the case of asymmetric information, with only one principal interested in both goods. Thereafter, we will

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[63] As in Martimort (1992).

discuss the likely adaptation of the Revelation Principle to the Common Agency setting and show that it fails in this situation. Finally, the generic framework of intrinsic Common Agency, with two principals competing through nonlinear price schedules will be solved.

5.1 The problem under perfect information

Consider an agricultural supply, characterized by a cost function: $C(q_1, q_2, \theta)$, where q_1 and q_2 are the two goods under scrutiny and θ is the efficiency parameter of the agricultural supply. θ is defined on support $[\underline{\theta}, \overline{\theta}]$, with density function f and cumulative distribution function F, and $d/d\theta(F(\theta)/f(\theta)) \geq 0$. The cost function of the agricultural supply has the following characteristics:[64]

- $C_i > 0$, $C_{ii} > 0$
- $C_\theta > 0$, $C_{i\theta} > 0$
- $C_{i\theta\theta} \geq 0$
- C_θ convex in $q_1, q_{2.}$

In a first approach, we consider that each principal derives a gross surplus $B_i(q_i)$, $i \in [1, 2]$ from the production of a quantity q_i of agricultural raw material. The function B_i is assumed increasing and concave. Thus, the principals only interact with

[64] The notation C_i stands for $\partial C/\partial q_i$.

one another through the cost function of the agricultural supply. There is no direct externality between the two principals: this situation is an instance of indirect externalities between the two principals. When one principal offers a contract to the common agent, she has to take into account the interaction of the other principal's contract on her own contractual offer. For instance, principals buy their agricultural raw material from the same agricultural supply, but the transformed goods are thereafter sold on unrelated markets.

Assuming that each principal perfectly knows the agent's characteristic, the problem of principal P_i is drastically simplified:

$$\max_{q_1(.),t_1(.)} B_1(q_1(\theta)) - t_1(\theta) \tag{5.34}$$
$$s.t.\ t_1(\theta) + t_2(\theta) - C(q_1(\theta), q_2(\theta), \theta) \geq 0$$

As P_1 perfectly knows the farmer's characteristic θ, she can maintain him at a zero profit level:

$$t_1(\theta) + t_2(\theta) - C(q_1(\theta), q_2(\theta), \theta) = 0 \tag{5.35}$$

Using (5.35), we may rewrite principal P_1's program:

$$\max_{q_1(.)} B_1(q_1(\theta)) + t_2(\theta) - C(q_1(\theta), q_2(\theta), \theta) \tag{5.36}$$

Maximization with respect to q_1 yields the first-best quantities: $B_1'(q_1^F(\theta)) = C_1(q_1^F(\theta), q_2^F(\theta), \theta),\ \forall\theta$. The perfect information framework leaves no rent to the farmer and achieves the first-best outcome. However, the sharing of the rent between the two principals is left unspecified.

5.2 The framework with 2 principals merged.

In this framework, we assume that the two principals are merged into one single entity, principal P_m, whose problem is to design a contract $\{q_1(.), q_1(.), t_m(.)\}$. The Revelation Principle can still apply, as the problem boils down to the relationship between one agent and one principal.

5.2.1 Information revelation by the agent

The farmer solves the following maximization program:

$$U(\theta) = \max_{\widehat{\theta}} t_m(\widehat{\theta}) - C(q_1(\widehat{\theta}), q_2(\widehat{\theta}), \theta) \tag{5.37}$$

Applying the envelope theorem to (5.37) yields the incitation constraint for the farmer:

$$\dot{U}(\theta) = -C_\theta(q_1(\theta), q_2(\theta), \theta) \tag{5.38}$$

As for the second-order conditions, we have the following result:

Lemma 1

The second-order condition of the farmer's program is satisfied if $q_1(\theta)$ *and* $q_2(\theta)$ *are non-increasing.*

Proof: Program (5.37)'s first-order condition may be written as:

$$\frac{\partial U}{\partial \widehat{\theta}} = \dot{t}_m(\widehat{\theta}) - C_1(q_1(\widehat{\theta}), q_2(\widehat{\theta}), \theta)\dot{q}_1(\widehat{\theta}) - C_2(q_1(\widehat{\theta}), q_2(\widehat{\theta}), \theta)\dot{q}_2(\widehat{\theta}) \tag{5.39}$$

The second-order condition is given by:

$$\begin{aligned} \frac{\partial^2 U}{\partial \widehat{\theta}^2} &= \ddot{t}_m(\widehat{\theta}) - C_{11}(q_1(\widehat{\theta}), q_2(\widehat{\theta}), \theta)\left(\dot{q}_1(\widehat{\theta})\right)^2 - C_1(q_1(\widehat{\theta}), q_2(\widehat{\theta}), \theta)\ddot{q}_1(\widehat{\theta}) \\ &\quad - C_{22}(q_1(\widehat{\theta}), q_2(\widehat{\theta}), \theta)\left(\dot{q}_2(\widehat{\theta})\right)^2 - C_2(q_1(\widehat{\theta}), q_2(\widehat{\theta}), \theta)\ddot{q}_2(\widehat{\theta}) \\ &\quad - 2C_{12}(q_1(\widehat{\theta}), q_2(\widehat{\theta}), \theta)\dot{q}_2(\widehat{\theta})\dot{q}_1(\widehat{\theta}) \end{aligned} \tag{5.40}$$

Differentiating equation (5.39) with respect to θ, taken in $\widehat{\theta} = \theta$ yields:

$$\begin{aligned} 0 &= \ddot{t}_m(\theta) - C_{11}(q_1(\theta), q_2(\theta), \theta)\left(\dot{q}_1(\theta)\right)^2 - C_1(q_1(\theta), q_2(\theta), \theta)\ddot{q}_1(\theta) \\ &\quad - C_{22}(q_1(\theta), q_2(\theta), \theta)\left(\dot{q}_2(\theta)\right)^2 - C_2(q_1(\theta), q_2(\theta), \theta)\ddot{q}_2(\theta) \\ &\quad - 2C_{12}(q_1(\theta), q_2(\theta), \theta)\dot{q}_2(\theta)\dot{q}_1(\theta) - C_{1\theta}(q_1(\theta), q_2(\theta), \theta)\dot{q}_1(\theta) \\ &\quad - C_{2\theta}(q_1(\theta), q_2(\theta), \theta)\dot{q}_2(\theta) \end{aligned} \tag{5.41}$$

As for the second-order condition, we must have $\partial^2 U/\partial \widehat{\theta}^2\Big|_{\widehat{\theta}=\theta} \leq 0$. Plugging (5.41) into (5.40) taken in $\widehat{\theta} = \theta$ gives the following inequality:

$$C_{1\theta}(q_1(\theta), q_2(\theta), \theta)\dot{q}_1(\theta) + C_{2\theta}(q_1(\theta), q_2(\theta), \theta)\dot{q}_2(\theta) \leq 0 \tag{5.42}$$

$C_{1\theta}$ and $C_{2\theta}$ being positive, the concavity of the agent's program is ensured if $q_1(\theta)$ and $q_2(\theta)$ are non-increasing.

Therefore, the program solved by Principal P_m takes the following form:[65]

$$\max_{t_m(.),\, q_1(.),\, q_2(.)} \int_{\underline{\theta}}^{\overline{\theta}} \{B_1(q_1(\theta)) + B_2(q_2(\theta)) - t_m(\theta)\} f(\theta) d\theta \tag{5.43}$$
$$s.t.\ \dot{U}(\theta) = -C_\theta(q_1(\theta), q_2(\theta), \theta)[\mu(\theta)]$$

Using (5.37), we substitute for $t_m(.)$ in Principal P_m's problem. Hence:

$$\max_{q_1(.),\, q_2(.),\, U(.)} \int_{\underline{\theta}}^{\overline{\theta}} \{B_1(q_1(\theta)) + B_2(q_2(\theta)) - C(q_1(\theta), q_2(\theta), \theta) \tag{5.44}$$
$$-U(\theta)\} f(\theta) d\theta$$
$$s.t.\ \dot{U}(\theta) = -C_\theta(q_1(\theta), q_2(\theta), \theta)\ [\mu(\theta)]$$

By an integration by parts, we get: $\int_{\underline{\theta}}^{\overline{\theta}} \mu(\theta)\dot{U}(\theta)d\theta = \mu(\overline{\theta})U(\overline{\theta}) - \mu(\underline{\theta})U(\underline{\theta}) - \int_{\underline{\theta}}^{\overline{\theta}} \dot{\mu}(\theta)U(\theta)d\theta.$

We therefore have the following program:

$$\max_{q_1(.),\, q_2(.),\, U(\overline{\theta}),\, U(\underline{\theta})} \int_{\underline{\theta}}^{\overline{\theta}} H_m(\theta)d\theta + \mu(\overline{\theta})U(\overline{\theta}) - \mu(\underline{\theta})U(\underline{\theta}) \tag{5.45}$$

The Hamiltonian H_m of this program can be written as: $H_m(q_1, q_2, \theta) = B_1(q_1(\theta)) + B_2(q_2(\theta)) - C(q_1(\theta), q_2(\theta), \theta) - U(\theta)\} f(\theta) + \mu(\theta)C_\theta(q_1(\theta), q_2(\theta), \theta) - \dot{\mu}(\theta)U(\theta)$. The Lagrangian $\mathcal{L}_m$ is defined by: $\mathcal{L}_m = \int_{\underline{\theta}}^{\overline{\theta}} H_m(\theta)d\theta + \mu(\overline{\theta})U(\overline{\theta}) - \mu(\underline{\theta})U(\underline{\theta})$.

The first-order condition with respect to $U(.)$ gives:

[65] We will assume that the quantities are not increasing and check *ex-post* that the property is effectively satisfied. $\mu(\theta)$ is the Lagrange multiplier attached of the incentive constraint.

$$\frac{\partial H_m}{\partial U} = -f(\theta) - \dot{\mu}(\theta) \leq 0 \ ; \ (U(\theta) \geq 0) \tag{5.46}$$

Derivation with respect to q_i, $i = \{1, 2\}$ yields:

$$\frac{\partial H_m}{\partial q_i} = \{B_i'(q_i(\theta)) - C_i(q_i(\theta), q_j(\theta), \theta)\} f(\theta) + \mu(\theta) C_{\theta i}(q_i(\theta), q_j(\theta), \theta) = 0 \tag{5.47}$$

The first-order conditions of the Lagrangian $\mathcal{L}_m$ with respect to $U(\overline{\theta})$ and $U(\underline{\theta})$ are the following:

$$\frac{\partial \mathcal{L}_m}{\partial U(\overline{\theta})} = \mu(\overline{\theta}) \leq 0 \ ; \ U(\overline{\theta}) \geq 0 \tag{5.48}$$

$$\frac{\partial \mathcal{L}_m}{\partial U(\underline{\theta})} = -\mu(\underline{\theta}) \leq 0 \ ; \ U(\underline{\theta}) \geq 0 \tag{5.49}$$

As $U(\underline{\theta}) > 0$, we get from equation (5.49) that $\mu(\underline{\theta}) = 0$

Moreover, we have $\mu(\theta) - \mu(\underline{\theta}) = \int_{\underline{\theta}}^{\theta} \dot{\mu}(x) dx = -\int_{\underline{\theta}}^{\theta} f(x) dx$ from (5.46).

Hence, $\mu(\theta) = -F(\theta)$

Replacing into (5.47), we derive the following optimal solution for q_i, $i = \{1, 2\}$:

$$B_i'(q_i(\theta)) - C_i(q_i(\theta), q_j(\theta), \theta) - \frac{F(\theta)}{f(\theta)} C_{\theta i}(q_i(\theta), q_j(\theta), \theta) = 0 \tag{5.50}$$

The second-order conditions are checked by differentiating (5.50) with respect to θ (omitting the arguments):

$$\dot{q}_i \left[B_i'' - C_{ii} - \frac{F}{f} C_{\theta ii} \right] - \dot{q}_j \left[C_{ij} + \frac{F}{f} C_{\theta ij} \right] - \frac{F}{f} C_{\theta\theta i} - C_{\theta i} \left[1 + \frac{d}{d\theta} \frac{F}{f} \right] = 0 \tag{5.51}$$

In the case of symmetric costs and benefits, we obtain a symmetric production of both goods, i.e. $q_i(\theta) = q_j(\theta) = q(\theta)$. Considering the properties of the cost and distribution functions, we get:

$$\dot{q} = \frac{\frac{F}{f} C_{\theta\theta i} + C_{\theta i} \left[1 + \frac{d}{d\theta}\frac{F}{f}\right]}{B_i'' - C_{ij} - C_{ii} - \frac{F}{f}[C_{\theta ii} + C_{\theta ij}]} \leq 0 \tag{5.52}$$

The quantity schedules being non-increasing, the second-order conditions are verified (owing to Lemma 1).

5.3 The problem of information revelation with two principals

The previous framework was not really complexified by the presence of two principals, since the two principals acted like one single merged principal. Thus, the Revelation Principle could continue to apply. When both regulators offer their own incentive schemes, the information revelation by the agent is more complicated, as he has to report his type twice, i.e. he announces a type $\widehat{\theta}_i$ to each principal P_i. It remains unclear whether an equivalent of the Revelation Principle exists in the case of two principals. We first present the Revelation Principle in the case of one principal, and then explain why a straightforward extension to the case of two principals is impossible.

5.3.1 The Revelation Principle

As exposed in Laffont and Martimort (2002), a direct revelation mechanism is a correspondence $g(.)$ from Θ to $\mathcal{A}$:[66] $g(\theta) = (q(\theta), t(\theta)), \forall\theta \in \Theta$. The principal commits to offering a transfer $t(\widetilde{\theta})$ in exchange of a production $q(\widetilde{\theta})$ from the agent if the agent announces that the value of his parameter is $\widetilde{\theta}$. A direct revelation mechanism is truthful if the agent finds worthwhile to announce his true type θ, $\forall\theta$, i.e. if the direct revelation mechanism satisfies the following incentive constraint:

$$t(\theta) - C(q(\theta), \theta) \geq t(\widetilde{\theta}) - C(q(\widetilde{\theta}), \theta), \text{ for all } \left(\theta, \widetilde{\theta}\right) \in \Theta^2. \tag{5.53}$$

However, a more general mechanism can be obtained when the communication between the principal and the agent is more complex than a simple announce of his type to the principal. Let $\mathcal{M}$ be the space of messages offered to the agent by a more general mechanism, which may be very complex. Conditionally to a given message m received from the agent, the principal asks for a production level $\widetilde{q}(m)$ and pays a transfer $\widetilde{t}(m)$ to the agent.

Facing such a mechanism, the θ-type agent chooses an optimal message $m^*(\theta)$ which is implicitely defined by:

$$\widetilde{t}(m^*(\theta)) - C(\widetilde{q}(m^*(\theta)), \theta) \geq \widetilde{t}(\widetilde{m}) - C(\widetilde{q}(\widetilde{m}), \theta) \tag{5.54}$$

[66] $\mathcal{A}$ is the space of allocations.

The mechanism $(\mathcal{M}, \widetilde{g}(.))$ induces an allocation rule $a(\theta) = (\widetilde{q}(m^*(\theta)), \widetilde{t}(m^*(\theta)))$ from the types Θ to the allocations $\mathcal{A}$. With these definitions, we may now formulate the Revelation Principle in the case of one agent.

Any allocation rule $a(\theta)$ obtained with a mechanism $(\mathcal{M}, \widetilde{g}(.))$ can also be implemented with a truthful direct revelation mechanism. Expressed graphically, the Revelation Principle takes the following form:

$$\Theta \overset{m^*(.)}{\longrightarrow} \mathcal{M} \overset{\widetilde{g}(.)}{\longrightarrow} \mathcal{A} \equiv \Theta \overset{g(.)=\widetilde{g}\circ m^*(.)}{\longrightarrow} \mathcal{A}$$

The proof is straightforward (following Laffont and Martimort, 2002): by composing $\widetilde{g}(.)$ and $m^*(.)$, a direct revelation mechanism mapping Θ into $\mathcal{A}$ can be constructed, i.e. $g(.) \equiv \widetilde{g} \circ m^*(.)$. The truthfullness of this direct revelation mechanism is proved using (5.54). As it is true for all $\widetilde{m}$, we take the case where $\widetilde{m} = m^*(\theta')$:

$$\widetilde{t}(m^*(\theta)) - C(\widetilde{q}(m^*(\theta)), \theta) \geq \widetilde{t}(m^*(\theta')) - C(\widetilde{q}(m^*(\theta')), \theta) \tag{5.55}$$

And, using the definition of $g(.)$, we get:

$$t(\theta) - C(q(\theta), \theta) \geq t(\theta') - C(q(\theta'), \theta),\ \forall\ (\theta, \theta') \text{ in } \Theta^2 \tag{5.56}$$

Hence, the direct revelation mechanism is truthful.

5.3.2 Can the Revelation Principle apply to Common Agency?

We now strive to determine the form that the Revelation Principle would take in the Common Agency framework and explain why it cannot work in such a context.

Let us consider $\mathcal{M}_1$ and $\mathcal{M}_2$ the message spaces of the agent, who reports his type to both principals. Let $m_1^*(\theta) \in \mathcal{M}_1$ and $m_2^*(\theta) \in \mathcal{M}_2$ be the two optimal messages. The agent will receive the allocations $\widetilde{g}_1(m_1^*(\theta)) = (q_1(m_1^*(\theta)), t_1(m_1^*(\theta)))$ and $\widetilde{g}_2(m_2^*(\theta)) = (q_2(m_2^*(\theta)), t_2(m_2^*(\theta)))$.

An equivalent version of the Revelation Principle in the case of the presence of two principals would be:

$$\Theta \longrightarrow \begin{array}{l} \xrightarrow{m_1^*(.)} \mathcal{M}_1 \xrightarrow{\widetilde{g}_1(.)} \mathcal{A}_1 \\ \xrightarrow{m_2^*(.)} \mathcal{M}_2 \xrightarrow{\widetilde{g}_2(.)} \mathcal{A}_2 \end{array} \equiv \Theta \longrightarrow \begin{array}{l} \xrightarrow{g_1(.)=\widetilde{g}_1 \circ m_1^*(.)} \mathcal{A}_1 \\ \xrightarrow{g_2(.)=\widetilde{g}_2 \circ m_2^*(.)} \mathcal{A}_2 \end{array}$$

A direct revelation mechanism would then be a couple of correspondences $\{g_1(\theta), g_2(\theta)\}$ from Θ^2 to $\mathcal{A}_1 \times \mathcal{A}_2$: $\{g_1(\theta), g_2(\theta)\} = \{(q_1(\theta), t_1(\theta)), (q_2(\theta), t_2(\theta))\}$.

Such a direct revelation mechansim $\{g_1(.), g_2(.)\}$ would be truthful if it were incentive-compatible for the agent to announce his true type (for all type) to both principals, i.e. if the direct revelation mechanism would satisfy the following incentive constraints, for all $(\widehat{\theta}_1, \widehat{\theta}_2, \theta) \in \Theta^3$:

$$t_1(\theta) + t_2(\theta) - C(q_1(\theta), q_2(\theta), \theta) \geq t_1(\widehat{\theta}_1) + t_2(\widehat{\theta}_2) - C(q_1(\widehat{\theta}_1), q_2(\widehat{\theta}_2), \theta) \tag{5.57}$$

However, it looks difficult to be able to reach such a result. Indeed, it seems unlikely that the optimal behavior for the agent be to report his type truthfully to both principals. As noted in Salanié (2005), the Revelation Principle cannot apply in this case. Assume that a general game in mechanisms implements an equilibrium $(q_1(\theta), q_2(\theta), t_1(\theta), t_2(\theta))$. For any agent of type θ, $t_1(\widehat{\theta}_1) - C(q_1(\widehat{\theta}_1), q_2(\theta), \theta)$ and $t_2(\widehat{\theta}_2) - C(q_1(\theta), q_2(\widehat{\theta}_2), \theta)$ must reach their maximum for $\widehat{\theta}_1 = \widehat{\theta}_2 = \theta$. However, C_{12}

being nonzero, it does not follow that $t_1(\widehat{\theta}_1) + t_2(\widehat{\theta}_2) - C(q_1(\widehat{\theta}_1), q_2(\widehat{\theta}_2), \theta)$ is maximal in $\widehat{\theta}_1 = \widehat{\theta}_2 = \theta$. Hence, the agent can do better than reveal his true type to both principals.

When one principal modifies the contract she offers to the agent, she not only modifies the choice of the activity level for her, she also modifies the level of the activity for her rival principal, as the marginal cost of one activity hinges upon the level of the other activity: there is an indirect externality between the two principals in their contractual offers (since $C_{12} \neq 0$).

5.4 Solving the problem when principals compete with nonlinear schedules.

The resolution of the problem takes the following path: in order to solve principal P_2's program, we consider that the latter offers a contract to the agent, taking account of the fact that the agent optimally responds to a nonlinear schedule $T_1(q_1)$ offered by principal P_1. Following Martimort and Stole (2002) and Salanié (2005), a new cost function which takes account of the agent's optimal behavior facing the contract offered by P_1 is introduced. This "residual" cost function vis-à-vis P_2 may be written as:[67]

[67] We symmetrically define $\widehat{C}^1(.)$ as:

$$\widehat{C}^1(q_1, \theta; T_2) = \min_{q_2} C(q_1, q_2, \theta) - T_2(q_2)$$

$$\widehat{C}^2(q_2, \theta; T_1) = \min_{q_1} C(q_1, q_2, \theta) - T(q_1) \tag{5.58}$$

This function determines the cost borne by the $\theta-$type farmer when he produces a quantity q_2 for principal P_2, knowing that he has optimized the quantity $Q_1(q_2, \theta; T_1)$ he chooses in the nonlinear schedule offered by P_1 and that he has received the payment corresponding to this quantity. We have:[68]

$$Q_1(q_2, \theta; T_1) = \arg\min_{q_1} C(q_1, q_2, \theta) - T_1(q_1) \tag{5.59}$$

Facing the nonlinear schedules offered by the two principals, the agent faces the following problem. Its maximum is equivalently determined by the three maximization programs below:

$$U(\theta) = \max_{q_1, q_2} T_1(q_1) + T_2(q_2) - C(q_1, q_2, \theta) \tag{5.60}$$

$$= \max_{q_2} T_2(q_2) - \widehat{C}^2(q_2, \theta; T_1)$$
$$= \max_{q_1} T_1(q_1) - \widehat{C}^1(q_1, \theta; T_2)$$

The solutions $q_1(\theta)$ and $q_2(\theta)$ of program (5.60) also verify: $q_1(\theta) = Q_1(q_2(\theta), \theta; T_1)$ and $q_2(\theta) = Q_2(q_1(\theta), \theta; T_2)$.

By application of the envelope theorem, the incitation constraint of the agent which must be taken into account by both principals can equivalently be written in

[68] Likewise,

$$Q_2(q_1, \theta; T_2) = \arg\min_{q_2} C(q_1, q_2, \theta) - T_2(q_2)$$

the three following ways, in relation with the three maximization programs presented above:

$$\dot{U}(\theta) = -C_\theta(q_1(\theta), q_2(\theta), \theta) = -\widehat{C}^2_\theta(q_2(\theta), \theta; T_1) = -\widehat{C}^1_\theta(q_1(\theta), \theta; T_2) \tag{5.61}$$

Principal P_2 solves the following maximization program, which accounts for the agent's participation and incitation constraints.

$$\max_{T_2(.), q_2(.)} E_\theta\{B^2(q_2(\theta)) - T_2(q_2(\theta))\}$$
$$s.t. \begin{cases} \dot{U}(\theta) = -\widehat{C}^2_\theta(q_2(\theta), \theta; T_1) \\ U(\theta) \geq 0 \end{cases}$$

As $\dot{U}(\theta) = -\widehat{C}^2_\theta(q_2(\theta), \theta; T_1) = -C_\theta(q_1(\theta), q_2(\theta), \theta) < 0$, the rent function is strictly decreasing in θ. It suffices that the participation constraint be binding in $\overline{\theta}$ to ensure that all types wish to participate. Moreover, as $T_2(q_2(\theta)) = U(\theta) + \widehat{C}^2(q_2(\theta), \theta; T_1)$, P_2's program can be rewritten as:

$$\max_{q_2(.), U(.)} \int_{\underline{\theta}}^{\overline{\theta}} \left\{ B^2(q_2(\theta)) - \widehat{C}^2(q_2(\theta), \theta; T_1) - U(\theta) \right\} f(\theta) d\theta$$
$$s.t. \begin{cases} \dot{U}(\theta) = -\widehat{C}^2_\theta(q_2(\theta), \theta; T_1) \\ U(\overline{\theta}) = 0 \end{cases} \tag{5.62}$$

By an integration by parts, we may replace $U(\theta)$ by the expression of its derivative in θ, $\dot{U}(\theta)$:

$$\int_{\underline{\theta}}^{\overline{\theta}} U(\theta) f(\theta)\, d\theta = -\int_{\underline{\theta}}^{\overline{\theta}} \dot{U}(\theta) F(\theta)\, d\theta = \int_{\underline{\theta}}^{\overline{\theta}} \widehat{C}^2_\theta(q_2(\theta), \theta; T_1) F(\theta)\, d\theta$$

It then remains for principal P_2 to solve the following maximization program:

$$\max_{q_2(.)} \int_{\underline{\theta}}^{\overline{\theta}} \left\{ B^2(q(\theta)) - \widehat{C}^2(q_2(\theta), \theta; T_1) - \frac{F(\theta)}{f(\theta)} \widehat{C}^2_\theta(q_2(\theta), \theta; T_1) \right\} f(\theta)\, d\theta \tag{5.63}$$

The first-order condition in q gives:

$$B^2_2(q^*_2(\theta)) - \widehat{C}^2_2(q^*_2(\theta), \theta; T_1) - \frac{F(\theta)}{f(\theta)} \widehat{C}^2_{\theta 2}(q^*_2(\theta), \theta; T_1) = 0 \tag{5.64}$$

A symmetric reasoning for regulator P_1 leads to:

$$B^1_1(q^*_1(\theta)) - \widehat{C}^1_1(q^*_1(\theta), \theta; T_2) - \frac{F(\theta)}{f(\theta)} \widehat{C}^1_{\theta 1}(q^*_1(\theta), \theta; T_2) = 0 \tag{5.65}$$

As $F(\underline{\theta}) = 0$, the solutions for the most efficient agent correspond to the first-best levels. It remains to replace the "residual" cost function $\widehat{C}^1_1$ (and its derivatives) by the "real" cost function C. This is done following Salanié (2005).

Applying the envelope theorem to program (**??**), the derivatives of these two functions with respect to parameter θ are linked by the following equation:

$$\widehat{C}^2_\theta(q_2, \theta; T_1) = C_\theta(Q_1(q_2, \theta; T_1), q_2, \theta) \tag{5.66}$$

Upon derivation with respect to q, we get:

$$\widehat{C}^2_{\theta 2}(q_2, \theta; T_1) = C_{\theta 1}(Q_1(q_2, \theta; T_1), q_2, \theta) \frac{\partial Q_1}{\partial q_2} + C_{\theta 2}(Q_1(q_2, \theta; T_1), q_2, \theta) \tag{5.67}$$

Replacing the "residual" cost functions with the real cost function in the two expressions above gives us:

$$B_1'(q_1^*(\theta)) - C_1(q_1^*(\theta), q_2^*(\theta), \theta) - \frac{F(\theta)}{f(\theta)} \left\{ C_{\theta 1}(q_1^*(\theta), q_2^*(\theta), \theta) + C_{\theta 2}(q_1^*(\theta), q_2^*(\theta), \theta) \left. \frac{\partial Q_2}{\partial q_1} \right|_{(q_1^*(\theta), q_2^*(\theta))} \right\} = 0 \tag{5.68}$$

$$B_2'(q_2^*(\theta)) - C_2(q_1^*(\theta), q_2^*(\theta), \theta) - \frac{F(\theta)}{f(\theta)} \left\{ C_{\theta 1}(q_1^*(\theta), q_2^*(\theta), \theta) \left. \frac{\partial Q_1}{\partial q_2} \right|_{(q_1^*(\theta), q_2^*(\theta))} + C_{\theta 2}(q_1^*(\theta), q_2^*(\theta), \theta) \right\} = 0 \tag{5.69}$$

Even if the first-order conditions are still not completely expanded, we may stop on these expressions to understand the supplementary distortion brought about by the competition between the two principals. Observe condition (5.68): as in the classical one principal-one agent framework, the distortion due to information revelation appears: $\frac{F(\theta)}{f(\theta)} C_{\theta 1}(q_1^*(\theta), q_2^*(\theta), \theta)$. However, a supplementary terms arises, reflecting the competition between the two principals: $\frac{F(\theta)}{f(\theta)} C_{\theta 2}(q_1^*(\theta), q_2^*(\theta), \theta) \left. \frac{\partial Q_2}{\partial q_1} \right|_{(q_1^*(\theta), q_2^*(\theta))}$. Hence, the competition between the two principals leads to greater distortions with respect to the merged framework in the case of complements $\left(\text{as } \left. \frac{\partial Q_2}{\partial q_1} \right|_{(q_1^*(\theta), q_2^*(\theta))} > 0 \right)$, while the case of substitutes results in a smaller distortion $\left(\text{as } \left. \frac{\partial Q_2}{\partial q_1} \right|_{(q_1^*(\theta), q_2^*(\theta))} < 0 \right)$. This intuitive result can be explained quite simply, following Martimort (1992). Principal P_1 offers a nonlinear schedule which reduces the level q_1, in order to decrease the agent's rent. In the case of substitutes, the agent chooses higher levels for q_2, therefore leading to high activity levels at the symmetric equilibrium. On the contrary, the agent chooses low levels for q_2 in the case of complements,[69] thus leading to low activity levels at the symmetric equilibrium.

Finally, $\partial Q_1/\partial q_2$ and $\partial Q_2/\partial q_1$ are replaced. The same path as Salanié (2005) is followed: applying the implicit functions theorem to program (5.58)'s first-order condition, we obtain:

$$T_1''\frac{\partial Q_1}{\partial q_2} = C_{11}\frac{\partial Q_1}{\partial q_2} + C_{12}$$

And, upon rearranging terms:

$$\frac{\partial Q_1}{\partial q_2} = \frac{C_{12}}{T_1'' - C_{11}}$$

Then, in order to replace T_1'' in the previous expression, we suppose that an equilibrium of the contract game $(q_1^*(\theta), q_2^*(\theta))$ has been reached, and differentiating the agent's first-order condition with respect to θ:

$$T_1''(q_1^*(\theta))\dot{q_1}^*(\theta) = C_{11}(q_1^*(\theta), q_2^*(\theta), \theta)\dot{q_1}^*(\theta) + C_{12}(q_1^*(\theta), q_2^*(\theta), \theta)\dot{q_2}^*(\theta) + C_{1\theta}(q_1^*(\theta), q_2^*(\theta), \theta)$$

which gives:

$$T_1''(q_1^*(\theta)) - C_{11}(q_1^*(\theta), q_2^*(\theta), \theta) = \frac{C_{12}(q_1^*(\theta), q_2^*(\theta), \theta)\dot{q}_2^*(\theta) + C_{1\theta}(q_1^*(\theta), q_2^*(\theta), \theta)}{\dot{q}_1^*(\theta)}$$

[69] The two goods produced by the farmer are not necessarily substitutes. We may consider the case of raw materials for the second-generation of biofuels which are complements in the agent's cost function: this is the case for crops which have elements used to be transformed into biofuels (the leaves), while the grain are used for food purposes. Moreover, the two goods under scrutiny may also be thought of as two types of energy crops, one for the first generation of biofuels, the other one for the second generation. Indeed, when the first plants for the second generation are on stream, the plants producing the first generation will still be active. Hence, these two generations of biofuels will undoubtedly be overlapping.

and finally:

$$\left.\frac{\partial Q_1}{\partial q_2}\right|_{(q_1^*(\theta),q_2^*(\theta))} = \frac{C_{12}(q_1^*(\theta),q_2^*(\theta),\theta)\dot{q_1}^*(\theta)}{C_{12}(q_1^*(\theta),q_2^*(\theta),\theta)\dot{q_2}^*(\theta)+C_{1\theta}(q_1^*(\theta),q_2^*(\theta),\theta)}$$

The expression of $\partial Q_2/\partial q_1$ is obtained in a symmetric way:

$$\left.\frac{\partial Q_2}{\partial q_1}\right|_{(q_1^*(\theta),q_2^*(\theta))} = \frac{C_{12}(q_1^*(\theta),q_2^*(\theta),\theta)\dot{q_2}^*(\theta)}{C_{12}(q_1^*(\theta),q_2^*(\theta),\theta)\dot{q_1}^*(\theta)+C_{2\theta}(q_1^*(\theta),q_2^*(\theta),\theta)}$$

Hence, the first-order solutions can finally be written as:

$$\begin{aligned}&B_2'(q_2^*(\theta)) - C_2(q_1^*(\theta),q_2^*(\theta),\theta)\\ &-\frac{F(\theta)}{f(\theta)}\left\{\frac{C_{\theta 1}(q_1^*(\theta),q_2^*(\theta),\theta)C_{12}(q_1^*(\theta),q_2^*(\theta),\theta)\dot{q_1}^*(\theta)}{C_{12}(q_1^*(\theta),q_2^*(\theta),\theta)\dot{q_2}^*(\theta)+C_{1\theta}(q_1^*(\theta),q_2^*(\theta),\theta)}+C_{\theta 2}(q_1^*(\theta),q_2^*(\theta),\theta)\right\}=0\end{aligned}$$

$$\begin{aligned}&B_1'(q_1^*(\theta)) - C_1(q_1^*(\theta),q_2^*(\theta),\theta)\\ &-\frac{F(\theta)}{f(\theta)}\left\{C_{\theta 1}(q_1^*(\theta),q_2^*(\theta),\theta)+\frac{C_{\theta 2}(q_1^*(\theta),q_2^*(\theta),\theta)C_{12}(q_1^*(\theta),q_2^*(\theta),\theta)\dot{q_2}^*(\theta)}{C_{12}(q_1^*(\theta),q_2^*(\theta),\theta)\dot{q_1}^*(\theta)+C_{2\theta}(q_1^*(\theta),q_2^*(\theta),\theta)}\right\}=0\end{aligned}$$

The system of differential equations that we finally attain is difficult to solve analytically. However, assuming that the agent's cost function takes the following form: $C(q_1,q_2,\theta)=\theta(q_1+q_2)+\frac{1}{2}(q_1^2+q_2^2)+\beta q_1q_2$, that principals' surpluses are linear : $B_1(q_1)=b^1q_1$ and $B_2(q_2)=b^2q_2$ and that the cumulative distribution function is the uniform function on $\Theta=[0,1]$, the problem becomes tractable:

$$\left\{\begin{array}{l} q_1^{nash}(\theta)=(b^1-\beta b^2)-2\theta[1-2\beta] \\ q_2^{nash}(\theta)=(b^2-\beta b^1)-2\theta[1-2\beta]\end{array}\right.$$

Proof.

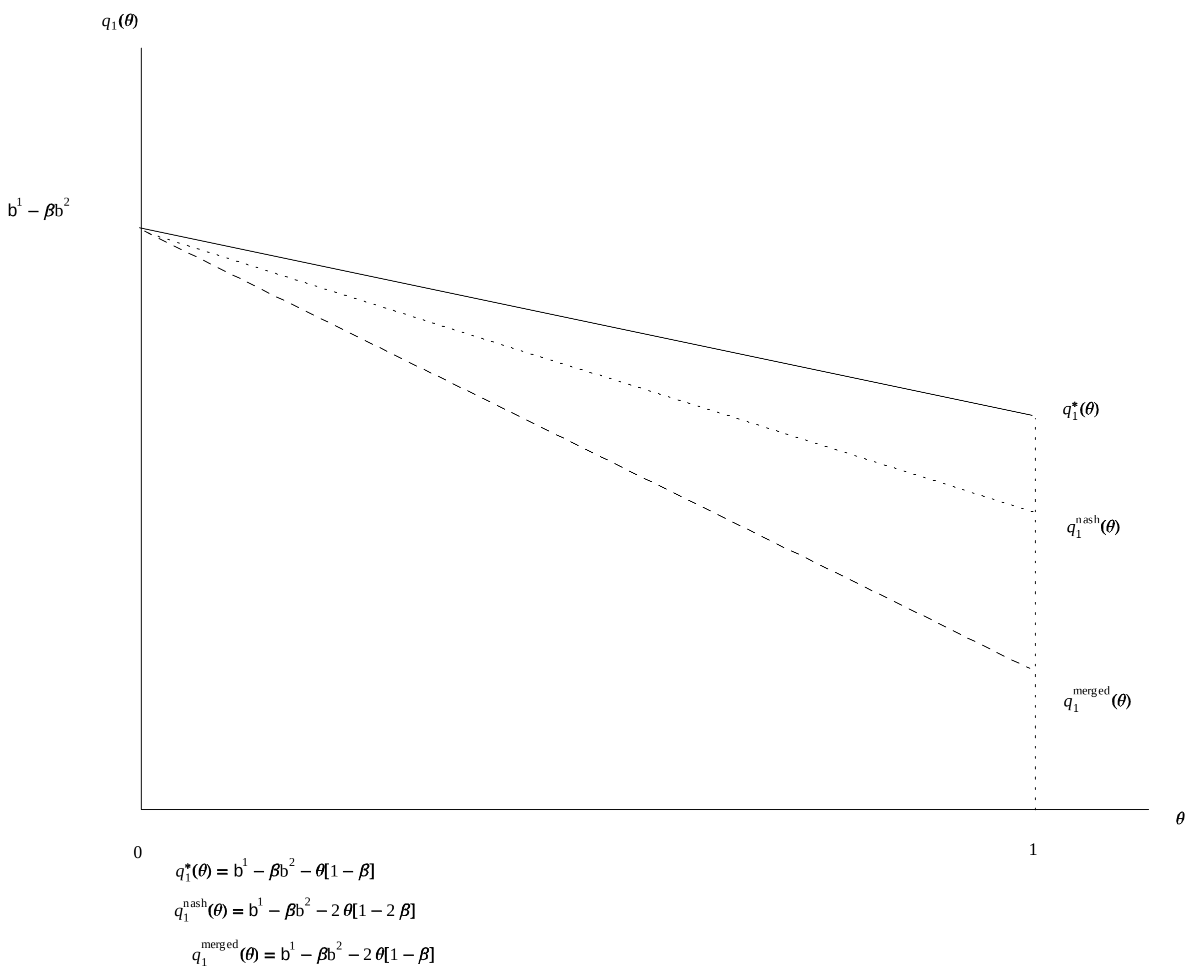

Fig. 5.5. Quantity schedules for q_1 in different settings, β small and > 0.

Taking $\beta \simeq 0$,[70] the differential system can be conveniently simplified:

$$b^1 - (\theta + q_1(\theta) + \beta q_2(\theta)) - \theta \{1 + \beta \dot{q_2}(\theta)\} = 0 \tag{5.70}$$

$$b^2 - (\theta + q_2(\theta) + \beta q_1(\theta)) - \theta \{1 + \beta \dot{q_1}(\theta)\} = 0 \tag{5.71}$$

Differentiating equation (5.71) with respect to θ,we get:

$$-1 - \dot{q_2}(\theta) - \beta \dot{q_1}(\theta) - 1 - \beta \dot{q_1}(\theta) - \theta \beta \ddot{q_1}(\theta) = 0 \tag{5.72}$$

Hence, $\dot{q_2}(\theta)$ can be expressed in the following way:

$$\dot{q_2}(\theta) = -2 - 2\beta \dot{q_1}(\theta) - \theta \beta \ddot{q_1}(\theta) \tag{5.73}$$

Rewriting (5.71), $q_2(\theta)$ takes the subsequent expression:

$$q_2(\theta) = b^2 - \theta - \beta q_1(\theta)) - \theta \{1 + \beta \dot{q_1}(\theta)\} \tag{5.74}$$

And, replacing $q_2(\theta)$ and $\dot{q_2}(\theta)$ in the equation (5.70):

$$b^1 - (\theta + q_1(\theta) + \beta q_2(\theta)) - \theta \{1 + \beta \dot{q_2}(\theta)\} = 0 \tag{5.75}$$

$$b^1 - 2\theta - q_1(\theta) - \beta[b^2 - \theta - \beta q_1(\theta)) - \theta \{1 + \beta \dot{q_1}(\theta)\}] - \theta\beta[-2 - 2\beta \dot{q_1}(\theta) - \theta \beta \ddot{q_1}(\theta)] = 0 \tag{5.76}$$

70 the approximation of $\frac{\beta \dot{q_1}^*(\theta)}{\beta \dot{q}_2^*(\theta)+1}$ leads to $\left.\frac{\beta \dot{q_1}^*(\theta)}{\beta \dot{q}_2^*(\theta)+1}\right|_{\beta=0} \simeq \beta \left[\frac{\dot{q_2}(\beta \dot{q_1}+1) - \beta \dot{q_1} \dot{q_2}}{(\beta \dot{q_2}+1)^2}\right]_{\beta=0} \simeq \beta \dot{q_2}$

Neglecting the terms in β^2, we finally obtain:

$$q_1^{nash}(\theta) = \left(b^1 - \beta b^2\right) - 2\theta[1 - 2\beta] \tag{5.77}$$

And, after replacing $q_1(\theta)$ in equation (5.71)

$$q_2^{nash}(\theta) = (b^2 - \beta b^1) - 2\theta[1 - 2\beta] \tag{5.78}$$

Conclusion

This chapter serves as a preamble to the developments led in the next chapter, in which the competition between two levels of regulation is dealt with. Even if the principals do not compete directly with one another (say, on the same market), the sharing of a common agent (here, farmers) leads to indirect contractual externalities between them, involving smaller (resp. higher) distortions in the case of substitutes (resp. complements) goods with respect to the benchmark scenario with merged principals. Hence, if we take the example of the production of substitutes by farmers (environment good and a "traditional" agricultural good), we end up with production levels that are higher in the case of a competition between two regulators with respect to the case in which these regulators would have cooperated.

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Chapter 6
The dual regulation of the European agricultural sector

Biofuels and environmental policies directed to agriculture share a common characteristic in the European Union (EU): the separation of regulatory powers between the EU and the Member State (MS) levels. Concerning agri-environmental policies, the examples are numerous, such as, e.g. cross-compliance and agri-environmental measures in the Common Agricultural Policy (CAP), the Directives concerning water (the most famous being the nitrates Directive), etc. As regards biofuel policies, the development of the first-generation shows this duality, with on the one hand the EU setting prominent objectives related to the environment (be it on climate change issues or on the certification of energy crops), while on the other hand the MS endowed with a large agricultural sector wishing to develop biofuels produced domestically and tending to put forwards income-related issues for their farmers.[71] The second-generation of biofuels, albeit not produced on an industrial level yet, is bound to raise similar regulatory issues. More generally, there is a tension between the strin-

[71] Moreover, biofuel policies might be considered as a first example of a re-nationalisation of the Common Agricultural Policy: the support schemes are decided at the level of the Member States (MS), and each MS is free to subsidize its own agriculture through biofuel production to the level deemed desirable. Re-nationalisation is a possible outcome for the future (post-2013)CAP, in which the burden of financing the agricultural sector would be transfered from the EU to the MS level. However, even if such an extreme scenario materializes for the future of the European Agricultural Policy, it seems that a common feature ought to outlive the dismantling of the CAP: environmental standards decided at the EU level. Hence, the regulation of the European agriculture would still be split up between a EU regulator, interested in the enforcement of stringent environmental standards and the MS regulator, which wants its agriculture to produce as much as possible.

gent environmental objectives that the EU entities (most often the Commission) wish to promote and the opposition of the MS willing to unleash the production capacities of their agricultural sector.

The environmental cross-compliance which appeared in the Agenda 2000 and was further reinforced under the Mid-Term Review (MTR) reform[72] shows that the Commission has gained the ability to link environmental and agricultural issues. This is due to growing concerns among the EU population of environmental problems related to agriculture. Besides, as the legitimacy of the CAP payments has faded away over time, putting forward environmental provisions in the CAP reforms is a means to justify the still important share of the CAP in the EU's budget (more than 40%, Bureau, 2007). Moreover, external pressures linked to the WTO negotiations have also helped the Commission to press for change.

Although the process that leads to CAP reforms is utterly complex, with numerous European and National structures involved in the process,[73] we strive to model the way the negotiations unfold by isolating two main actors: the EU Commission and an agricultural MS who opposes new environmental constraints imposed on the agricultural activities.[74] The European Commission is therefore considered as the environmental regulator,[75] whereas the agricultural MS make up the "production"

[72] Proposal in 2002 by the European Commission, agreement in 2003.

[73] The Commission of course, is a key actor along with the Council of Ministers which is the executive body. However, there are numerous committees which are consulted in the reform process, e.g. the Committee of the regions, the Committee of permanent representatives, the special Committee on agriculture, the management Committee, etc. (Greer, 2005). With the enactment of the Lisbon Treaty (forecasted before the European elections of 2009), the European Parliament will gain a power of co-decision in the next CAP reforms.

[74] Ireland, Greece and France are some examples of MS reluctant to new environmental provisions (Greer, 2005)

[75] Note that the interests of the MS wishing to enforce stringent environmental standards have their objec-

regulator. While the EU Commission presses the MS to respect high environmental standards, the agricultural MS wishes to produce as many agricultural commodities as possible, in order to endow its agricultural sector with high incomes. Both entities regulate the agricultural sector of the agri-MS, which is therefore asked to produce two kinds of goods: an environmental good (in the form of an environmental effort, e.g. a decrease in the use of polluting inputs) and a "classical" production good.

The aim of this chapter is to study the implications from the separation of regulatory powers. More precisely, the focus will be set on the timing of the regulation. The order in the regulatory decisions are by no means a theoretical abstraction which would arbitrarily designate the identity of the Stackelberg leader. The sequentiality stems from the expression of a political power (taken in a broad sense) to impose its own agenda to the other regulatory entity and to the regulated sector, i.e. the agricultural supply. The methodological framework chosen to modelize these regulation aspects is the Common Agency theory (presented in its general setting in *Chapter 5*), with a special focus on the Stackelberg form of the game. As explained in the previous chapter, Common Agency games involve 2 (or more) principals competing through contractual offers made to a common agent, for whom they share a common probability function concerning his technical ability θ.

The evolution towards stiffer environmental commitments in the CAP reforms can be viewed as a change in the structure of the game being played between the

tives aligned with the environmental regulator.

European Commission and the MS in defining the European agricultural policy. Our purpose is to modelize two different negotiation settings:

- The past CAP reforms did not give the prevalence to environmental problems. Hence, the setting of the game can be considered as a simultaneous move, Nash game, as no clear leadership emerges.

- In the most recent CAP reforms, the setting of the game being played is profoundly altered: the European Commission favoring strict environmental standards can now be considered as a Stackelberg leader, who imposes its environmental policy (for all the reasons previously cited). The MS can only adopt what has been decided with respect to the environment.

The aim of this chapter is not primarily to study the implications of regulatory separation *per se* with respect to a merged regulation setting. The chapter is rather aimed at addressing the implications of being first (i.e. being the Stackelberg leader) when co-regulating a sector for which the efficiency is unknown.

This chapter builds upon the theory of Common Agency initiated by Stole (1991) and Martimort (1992). More precisely, our purpose is to study the implications of separated regulatory powers when one agency is in charge of the environment and the other is interested in the production activity of the entity they regulate. The first paper on the dual regulation of an activity under asymmetric information is due to Baron (1985). In his seminal paper, Baron studies the regulation of an electricity generating plant which is controlled by a public utilities commission and an environmental regulator (the Environmental Protection Agency). The plant is a monopolist which has some private information about the effectiveness of its abatement alternatives, and the environmental regulator acts as a Stackelberg leader. The problem is that the agents who bear the abatement costs and those who get the benefits of an emission abatement policy belong to two different jurisdictions. Hence, the interests of the two regulators (which represent different jurisdictions) are in conflict. In the noncooperative equilibrium, the EPA sets a very stringent standard and a very high emission fee. The EPA and the firm prefer the noncooperative framework, while the Public Utilities Commission prefers the cooperative outcome. In Martimort (1996), a rather similar analysis is conducted: there are two regulators which are called upon to contribute to the financing of a large project (e.g., the construction of a nuclear power plant). However, the regulators only have a prior information about the cost of the project. The author compares different regulation structures: cooperation, separation under Nash or Stackelberg setting. The regulators offer too small transfers in the Nash separated regulation case with respect to the cooperative outcome. The distortions are even larger in the Stackelberg framework. A more complex analysis is conducted in Martimort (1999): the regulators offer payments in return of the production of a given good in quantity q. The setting is therefore more complex than the decision of building or not a given project. Although the scope of the article is much larger than the Stackelberg Common Agency setting (it notably deals with renegotiation), it nonetheless reaches a powerful result with respect to the sharing of the cost burden between the two principals: the follower bears the larger part of the production costs of the agent. Last, Martimort (2006) offers a methodology for dealing with the variations of the follower's profit in the Stackelberg Common Agency framework. This study goes a step further with respect to this literature since it presents a Stackelberg framework of a Common Agency setting where the agent produces a different good for each principal.

In this chapter, we first sum up the main results concerning the differences between separation and integration of the regulatory powers. Then, we present the Stackelberg perfect information framework, where both agencies perfectly know the agricultural sector's technical parameter. The asymmetric information framework follows. Finally, we compare the welfare levels in the different frameworks under scrutiny.

6.1 Regulation separation vs integration

An interesting policy question is to discuss the various regulatory structures and to determine which one is optimal for the different economic agents involved. We compare two frameworks for regulation. First, we study the optimal production of an environmental and an agricultural good under cooperation, then we study how the competition between the two regulators leads to different conclusions. The two frameworks are built under the assumption of asymmetric information between the agricultural sector and its regulators.

6.1.1 Modelling choices

The agricultural sectors of the MS wishing to promote the production aspects in agriculture are asked to produce two types of goods. The first good, referred to as the environmental good e, is controlled by an environmental regulator in charge of promoting the production of an environmental good (environmental effort in the form of polluting input reduction). The second good q is an agricultural crop. The two goods are produced by the agricultural sector of the MS (i.e. a MS supporting actively the income of its agricultural sector), each farm being characterized by a cost function $C(e, q, \theta)$, increasing and convex in both goods produced, θ being a parameter that reflects the technical ability of the farmer, and his private information. The two goods are substitutes in the farm sector's cost function : $C_{eq} > 0$. We also have $C_{\theta} > 0$ (the total cost increases in θ), $C_{e\theta} > 0$ (the marginal cost for producing the environmental good e increases in θ) and $C_{\theta q} > 0$ (the marginal cost for producing the energy crop q also increases in θ). Moreover, we assume that $C_{\theta\theta} = 0$ for simplicity. $B^e(.)$ and $B^q(.)$ are the regulators' surpluses. They are function of e and q respectively and are supposed increasing and concave.

In most of the analysis conducted in the following, we assume that both regulators share a common prior belief over the technical parameter θ, embodied in the distribution and density functions $f(\theta)$ and $F(\theta)$ respectively, with support $[\underline{\theta}, \overline{\theta}]$. Besides, we assume that the distribution function satisfies the following monotonicity condition: $\Lambda'(\theta) > 0$, where $\Lambda(\theta) = F(\theta)/f(\theta)$.

The regulatory framework under scrutiny will be modelled through the use of the Common Agency theory, which deals with the contractual relationships between two principals and one agent. More precisely, the Common Agency framework we are referring to is the intrinsic Common Agency framework, in which the agent is compelled to contract with both principals or to elect his outside opportunity.[76] (see Stole, 1991 and Martimort, 1992).

Let then P_e be the environmental regulator (the European Commission willing to impose the production of a level e of an environmental good) and P_q the production regulator, which is an agri-MS willing to promote income issues for its agricultural sector above all. Regulator P_e (in charge of the environment) offers a nonlinear price schedule $S(e)$ to the agent, while principal P_q offers a schedule $T(q)$. $S(e)$ can be regarded as a subsidy to produce the environmental good, while $T(q)$ is the "productive" payment to agriculture. Facing these two nonlinear schedules, the farmer (the agent) must pick on his two preferred quantities $(e(\theta), q(\theta))$ that maximize his program.

6.1.2 Regulators integration

In this part we study the framework in which both regulatory powers are in the hands of a single, merged regulator.

[76] In the other family of Common Agency models, the agent can choose to contract with one or both principals or neither of them if his outside opportunity is more appealing. These situations are referred to as *delegated Common Agency,* since the existence of the Common Agency is delegated by the choice of the agent, who prefers to contract with both principals rather than to choose the exclusive dealing outcome.

The two regulators cooperate in the setting up of nonlinear payment schedules $S(e)$ and $T(q)$. Under cooperation, regulators P_e and P_q share the same maximization program, which can be considered as the program solved by a merged regulator P_m in charge of both the environment and the agricultural production aspects.

The θ-type farmer's maximization program is the following:[77]

$$U(\theta) = \max_{e,q} S(e) + T(q) - C(e, q, \theta) \tag{6.79}$$

Applying the envelope theorem to (6.79), we get:

$$\dot{U}(\theta) = -C_\theta(e(\theta), q(\theta), \theta) < 0 \tag{6.80}$$

where $e(\theta)$ and $q(\theta)$ are the optimal quantities chosen by the θ-type farmer.

Thus, principal P_m solves the following program:

$$\begin{aligned} &\max_{S(.),T(.),e(.),q(.)} E_\theta\{B^e(e(\theta)) + B^q(q(\theta)) - S(e(\theta)) - T(q(\theta))\} \\ &s.t. \begin{cases} \dot{U}(\theta) = -C_\theta(e(\theta), q(\theta), \theta) \\ U(\overline{\theta}) = 0 \end{cases} \end{aligned}$$

Using (6.79), we can replace $S(e(\theta)) + T(q(\theta))$ in P_m's maximand. The principal's program can now be written as:

$$\begin{aligned} &\max_{e(.),q(.),U(.)} \int_{\underline{\theta}}^{\overline{\theta}} \{B^e(e(\theta)) + B^q(q(\theta)) - C(e(\theta), q(\theta), \theta) - U(\theta)\} f(\theta) d\theta \\ &s.t. \begin{cases} \dot{U}(\theta) = -C_\theta(e(\theta), q(\theta), \theta) \\ U(\overline{\theta}) = 0 \end{cases} \end{aligned}$$

[77] The second-order necessary conditions are identical to the ones derived in Chapter 5, Lemma 1.

Following an integration by parts, we can replace $U(\theta)$ in the program's maximand by the expression of its derivative and use (6.80) to obtain:

$$\max_{e(.),q(.)} \int_{\underline{\theta}}^{\overline{\theta}} \{B^e(e(\theta))+B^q(q(\theta))-C(e(\theta),q(\theta),\theta)-\Lambda(\theta)C_\theta(e(\theta),q(\theta),\theta)\}f(\theta)d\theta \quad (6.81)$$

It then only remains to solve this program pointwise with respect to each choice variables. The following first-order conditions are derived:

$$\begin{cases} B^e_e(e^*(\theta)) = C_e(e^*(\theta),q^*(\theta),\theta) + \Lambda(\theta)C_{\theta e}(e^*(\theta),q^*(\theta),\theta) \\ B^q_q(q^*(\theta)) = C_q(e^*(\theta),q^*(\theta),\theta) + \Lambda(\theta)C_{\theta q}(e^*(\theta),q^*(\theta),\theta) \end{cases} \quad (6.82)$$

Assume that the agent's cost function takes the following form: $C(e,q,\theta) = \theta(e+q) + \frac{1}{2}(e^2+q^2) + \beta eq$, that principals' surpluses are linear : $B^e(e) = b^e e$ and $B^q(q) = b^q q$ and that the cumulative distribution function is the uniform function on $\Theta = [0,1]$. Moreover, considering β small and neglegting the terms in β^2, the quantity schedules are given in the next proposition:

Proposition 5 *In the case of merged regulatory powers, the quantities of the two goods are:*

$$e^{merged}(\theta) = b^e - \beta b^q - 2\theta(1-\beta)$$

$$q^{merged}(\theta) = b^q - \beta b^e - 2\theta(1-\beta)$$

The cooperative outcome leads to a solution identical to the traditional principal-agent relationship. The regulatory powers being merged, there is of course no contractual externality between the two principals. However, this framework looks hardly implementable when deciding to launch the production of second-generation biofuels both for agricultural-income and environmental positive externalities reasons. Even if the regulators belong to the same constituency, it seems very likely that there would be at least a competition between the ministries in charge of the agriculture and the environment.

6.1.3 Regulators separation

As already pointed out in the introduction, the setting of a regulatory separation can correspond to the past agricultural reforms in the EU, when two regulators were facing off: the European Commission and the agri-MS. The more agriculture-oriented MS were pushing to maintain the economic instruments of the CAP (price supports, quotas, high tariff rates, export subsidies, etc.) to keep a high level of production, while the Commission was in favor of market liberalization and for transfers from the first (production) to the second (rural development) pillar.

In the CAP reforms that have been undertaken, each group has striven to push its own agenda. The process of negotiation can therefore be modelled as a Nash contract competition between two regulators: the "environmental" principal P_e and the "productive" principal P_q.[78] The negotiation ends up as a Nash equilibrium of their contracting offers, which take into account the information asymmetry between each principal and the agent, i.e. the MS's agricultural sector. The presence of 2

[78] A similar setting has already been presented in Chapter 5. Therefore, the derivation of the results has been placed in the appendix to this Chapter.

competing principals makes the model more technical. The resolution of the problem takes the following path: in order to solve principal P_q's program, we consider that the latter offers a contract to the agent, taking account of the fact that the agent optimally responds to a nonlinear schedule $S(e)$ offered by principal P_e, in charge of the environment.

The framework is exactly identical to the one developed in *Chapter 5 (5.4)*, albeit the notations. Hence, we skip the details (placed in appendix B.) and state the following lemma:

Lemma 6 *When the regulatory powers are separated, the optimal quantities of the two goods $e^*(\theta)$ and $q^*(\theta)$ are defined*

$$\begin{cases} b^e - (\theta + e^*(\theta) + \beta q^*(\theta)) - \Lambda(\theta)\left\{1 + \frac{\beta \dot{q}^*(\theta)}{\beta \dot{e}^*(\theta)+1}\right\} = 0 \\ b^q - (\theta + q^*(\theta) + \beta e^*(\theta)) - \Lambda(\theta)\left\{\frac{\beta \dot{e}^*(\theta)}{\beta \dot{q}^*(\theta)+1} + 1\right\} = 0 \end{cases}$$

In the Nash framework, similar computations give the following quantity schedules:

$$\begin{cases} e^{nash}(\theta) = b^e - \beta b^q - 2\theta[1 - 2\beta] \\ q^{nash}(\theta) = b^q - \beta b^e - 2\theta[1 - 2\beta] \end{cases} \tag{6.83}$$

The quantities of the two goods are greater than under merged regulation: $e^{nash}(\theta) \geq e^{merged}(\theta)$ and $q^{nash}(\theta) \geq q^{merged}(\theta)$, with a strict equality for $\theta = \underline{\theta}$.

Proof: see appendix C.

In the case of a small substituability between the environmental and the productive goods (i.e. $\beta \approx 0$), we observe that the regulatory separation ends up with a more important production of both goods (which are substitutes) in equilibrium with respect to the merged regulatory setting. This comparative statics result has already been explained in Stole (1991) and Martimort (1992): Principal P_e will offer a nonlinear schedule which reduces the level of activity e, in order to decrease the agent's rent. In the case of substitutes, the agent chooses higher levels of activity for q, therefore leading to high activity levels at the symmetric equilibrium.

6.2 The Stackelberg Common Agency framework

In a political economy point of view, the Stackelberg framework corresponds to the imposition of an environmental regulation prior to any productive schedule. This new regulatory setting marks a departure with respect to the simultaneous move regulation in which no regulator was able to impose her own agenda to the other. This new framework marks the pre-eminence of the environmental aspects in the agricultural reforms. It can be viewed as a shift from a Nash to a Stackelberg setting, in which the European Commission plays first (it is represented as the Stackeberg leader), imposing a stringent environmental schedule.

As observed by Greer (2005): "The European Commission is often said to be in favourable position to set agendas, partly because of its formal monopoly on policy initiation and partly because it can draw selectively from national agendas. [...] Undoubtedly there have been occasions when the Agriculture Directorate has shaped the agenda, for example Commissioner Fischler's epousal of broad rural development in the mid-1990s and his role in the MTR."

The study is conducted under perfect and asymmetric information. In the latter case, both regulators must build an incentive scheme taking account of the fact that the agricultural sector acts strategically in revealing his type to the principals.

6.2.1 The perfect information case

The regulatory framework where both regulators are perfectly informed about the farm sector's productivity is first presented. Let then $\{s(\theta), e(\theta)\}_{\theta\in\Theta}$ and $\{t(\theta), q(\theta)\}_{\theta\in\Theta}$ be the two incentive schemes offered by regulators P_e and P_q respectively. The timing of the game is the following:

- First, the environmental regulator (principal P_e) announces the contracts $\{s(\theta), e(\theta)\}_{\theta\in\Theta}$. Said differently, the farmer of technical ability θ will accept to produce an environmental good in quantity $e(\theta)$, and will receive a payment $s(\theta)$ (an environmental subsidy) from the EU regulator to reward him for his environmental production.

- Then, the MS (principal P_q), chooses her own payment scheme $\{t(\theta), q(\theta)\}_{\theta\in\Theta}$, taking into account what has been decided environment-wise at the EU level. In exchange of a production subsidy $t(\theta)$, the farmer commits to produce the "productive" good in quantity $q(\theta)$.

- Last, each agent θ announces his type θ to each regulator. He produces $(e(\theta), q(\theta))$ and receives the total payment $s(\theta) + t(\theta)$.

Principal P_q's program (the follower) can be written as:

$$\max_{\{q(.),t(.)\}} B^q(q(\theta)) - t(\theta) \tag{6.84}$$
$$s.t. \;\; s(\theta) + t(\theta) - C(e(\theta), q(\theta), \theta) \geq 0$$

Knowing the farmer's parameter θ and the contracts $\{s(\theta), e(\theta)\}_{\theta \in \Theta}$ offered by the Stackelberg leader, regulator P_q can maintain the farmer at a zero profit level, for all θ. The farmer's participation constraint is therefore binding and we can replace t in P_q's program:

$$\max_{q(.)} B^q(q(\theta)) + s(\theta) - C(e(\theta), q(\theta), \theta) \tag{6.85}$$

For all θ, the first-order condition in q can therefore be written as:

$$B^q_q(q^*(\theta)) = C_q(e(\theta), q^*(\theta), \theta) \tag{6.86}$$

Principal P_q therefore induces an efficient production for all θ. We solve for P_e's program in order to know how the two regulators share the burden of the farmer's costs. The environmental regulatory agency P_e plays first. She must take into account P_q's optimal solution, and the agent's participation constraint as well as P_q's no-veto constraint: principal P_q must be guaranteed a non-negative social welfare when she is called upon to play after principal P_e. The program may thus be written as follows:

$$\max_{\{e(.),s(.)\}} B^e(e(\theta)) - s(\theta) \tag{6.87}$$

$$s.t. \begin{cases} B_q^q(q^*(\theta)) - C_q(e(\theta), q^*(\theta), \theta) = 0 \\ B^q(q(\theta)) - t(\theta) \geq 0 \\ s(\theta) + t(\theta) - C(e(\theta), q(\theta), \theta) \geq 0 \end{cases}$$

Writing the Lagrangian of P_e's program (where ν is the Lagrange multiplier attached to the first constraint):

$$\max_{e(.),q(.)} B^e(e(\theta)) + B^q(q(\theta)) - C(e(\theta), q(\theta), \theta) + \nu\{B_q^q(q^*(\theta)) - C_q(e(\theta), q^*(\theta), \theta)\} \tag{6.88}$$

The first-order condition is:

$$B_e^e(e^*(\theta)) = C_e(e^*(\theta), q^*(\theta), \theta) \ \forall\theta \tag{6.89}$$

For each θ-type farmer, P_e manages to impose the Pigouvian level:

$$B_q^q(q^{**}(\theta)) - C_q(e(\theta), q^{**}(\theta), \theta) + \nu\{B_{qq}^q(q^{**}(\theta)) - C_{qq}(e(\theta), q^{**}(\theta), \theta)\} = 0 \tag{6.90}$$

As we must have $B_q^q(q^{**}(\theta)) - C_q(e(\theta), q^{**}(\theta), \theta) = 0$ and $B_{qq}^q(q^{**}(\theta)) - C_{qq}(e(\theta), q^{**}(\theta), \theta) \neq 0$, it leads to $\nu = 0$.

In the perfect information framework, each regulator therefore manages to impose her first-best quantities. However, contrary to the Nash perfect information outcome where the respective shares of the agent's cost borne by each principal is left unspecified (see Martimort, 1992), the Stackelberg outcome selects an equilibrium, namely the one in which the leader succeeds in leaving her follower pay a large chunk of their common cost burden. As P_e can control P_q's subsequent behavior since she plays first, she will maintain her follower and the farmer at a zero social welfare level. The game played in Nash was flawed with a multiplicity of equilibria. This is no longer the case in a Stackelberg framework, in which the most favorable outcome for the leader is selected. This result seems intuitively appealing. These results are summed up in the proposition below:

Proposition 7 *In the perfect information, Stackelberg framework, both goods (the environmental good and the agricultural raw material) are produced at their first-best levels. The agent and the MS earn no rent, while the environmental regulator manages to keep all the social welfare for her.*

Corollary 8 *In the case where the marginal valuations of both principals are equal, the payments can be conveniently expressed:*

$$t(\theta) = bq(\theta) = b\left(\frac{b-\theta}{1+\beta}\right)$$

and

$$s(\theta) = \frac{\theta(b-\theta)}{1+\beta}$$

Proof: see appendix D.

We therefore have $t(\theta) > s(\theta)$ for all θ: principal P_q contributes more to the reimbursement of the agent's costs, by the mere fact that she plays second, after principal P_e, who has some leeway to maintain her follower at a zero social welfare level. The environmental regulator will impose her desired level of environmental good production (at the Pigouvian level) and manage to contribute in the least important way to the production of the couple {environmental good, agricultural good}. In the next section, we solve the same regulatory problem, but in the case where farmers have a private information on their production costs.

6.2.2 The imperfect information framework

This section deals with the regulatory framework where both regulators are imperfectly informed about the farm sector's productivity, knowing only a prior distribution of the agent's type. Let then $S(e)$ and $T(q)$ be the two nonlinear payment schedules offered by regulators P_e and P_q respectively. Contrary to the previous perfect information framework, where incentive schemes were used, we prefer to use nonlinear schedules in the asymmetric information case. The timing of the game is the following:

- First, the environmental regulator (principal P_e) announces her nonlinear schedule $S(e)$. Said differently, this means that a farmer who chooses to produce the environmental good in quantity e will receive a payment $S(e)$ (environmental subsidy) from the EU regulator to reward him for his environmental production.

- The MS (principal P_q) then chooses her own nonlinear payment schedule $T(q)$, taking into account what the EU Commission has decided with respect to the environment. In exchange of producing crops in quantity q, the farmer will receive $T(q)$ in payment from the MS.

- Last, the agent picks on his preferred quantities e and q in each regulator's nonlinear payment schedules, thus receiving a total payment $S(e)+T(q)$.

We first consider principal P_q's problem (the follower).[79] As in the Nash framework, the following first-order condition is obtained:

$$B_q^q(q^*(\theta)) - \widehat{C}_q^q(q^*(\theta),\theta;S) - \Lambda(\theta)\widehat{C}_{\theta q}^q(q^*(\theta),\theta;S) = 0 \tag{6.91}$$

Principal P_e (who is the Stackelberg leader) has to take into account in her own program principal P_q's behavior, her follower. This control by principal P_e of principal P_q's social welfare function is realized through P_q's *ex ante* social welfare function, for a given $\theta-$type agent, which entails the information cost in addition to the production cost.

$$\begin{aligned} V^q(\theta;S) &= \max_q B^q(q) - \widehat{C}^q(q,\theta;S) - \Lambda(\theta)\widehat{C}_\theta^q(q,\theta;S) \qquad (6.92) \\ &= B^q(q^*(\theta)) - \widehat{C}^q(q^*(\theta),\theta;S) - \Lambda(\theta)\widehat{C}_\theta^q(q^*(\theta),\theta;S) \\ &= B^q(q^*(\theta)) - \widehat{C}^q(q^*(\theta),\theta;S) + \Lambda(\theta)\dot{U}(\theta) \end{aligned}$$

Just in the same way as a principal has to consider the evolution of the agent's informational rent in a classical principal-agent problem, principal P_e has to take into

[79] Note that the problem will be solved for the simple specifications presented above as regards the farmer's cost function, the regulators' surplus functions and the types' distribution function.

account in her own maximization program the evolution of principal P_q's *ex ante* social welfare, in addition to the agent's incentive and participation constraints. Moreover, principal P_e will have to ensure that principal P_q will obtain a non-negative *ex ante* social welfare: $V^q(\theta; S) \geq 0$, so as to be sure that she wishes to offer a contract to the whole set of farmers.

The evolution of the *ex ante* social welfare of principal P_q is obtained by applying the envelope theorem to program (6.92):[80]

$$\frac{dV^q(\theta; S)}{d\theta} = -(1 + \dot{\Lambda}(\theta))\widehat{C}^q_\theta(q^*(\theta), \theta; S) - \Lambda(\theta)\widehat{C}^q_{\theta\theta}(q^*(\theta), \theta; S) \tag{6.95}$$

We first assume that $\frac{dV^q(\theta;S)}{d\theta} < 0$, although there may be occurrences where this expression is nill. We give sufficient conditions for this inequality to be verified in appendix F.

Principal P_q's *ex ante* social welfare therefore evolves in a monotonic way. The non-negativity constraint implies that $V^q(\overline{\theta}) = 0$ and that $V^q(\theta) > 0$ for all $\theta < \overline{\theta}$. This result is in sharp contrast with the outcome of the Stackelberg game under perfect information. In the framework under scrutiny, principal P_q, although playing after principal P_e, manages to withhold a non-zero social welfare.

[80] Note that, although we have assumed that $C_{\theta\theta} = 0$, this does not imply that $\widehat{C}^q_{\theta\theta} = 0$. Indeed, we have:

$$\widehat{C}^q_\theta(q, \theta; S) = C_\theta(E(q, \theta; S), q, \theta) \tag{6.93}$$

Hence,

$$\widehat{C}^q_{\theta\theta}(q, \theta; S) = C_{\theta e}(E(q, \theta; S), q, \theta)\frac{\partial E}{\partial \theta}(q, \theta; S) + C_{\theta\theta} = C_{\theta e}(E(q, \theta; S), q, \theta)\frac{\partial E}{\partial \theta}(q, \theta; S) \tag{6.94}$$

By integration, the level of the *ex ante* social welfare $V^q(\theta; S)$ is derived:

$$V^q(\overline{\theta}; S) - V^q(\theta; S) = \int_{\theta}^{\overline{\theta}} \dot{V}^q(x; S)dx$$

The constraint $V^q(\theta; S) \geq 0$ being binding in $\overline{\theta}$, we get:

$$V^q(\theta; S) = \int_{\theta}^{\overline{\theta}} \left\{(1 + \dot{\Lambda}(x))\widehat{C}^q_x(q^*(x), x; S) + \widehat{C}^q_{xx}(q^*(x), x; S)\right\} dx$$

P_e maximizes her expected welfare, under the agent's participation and incitation constraints and under principal P_q's welfare evolution and no-veto constraints ($V^q(\theta; S) \geq 0$).

$$\max_{S(.), e(.)} E_\theta\{B^e(e(\theta)) - S(e(\theta))\} \tag{6.96}$$

$$s.t. \begin{cases} \dot{U}(\theta) = -\widehat{C}^e_\theta(e(\theta), \theta; T) \\ U(\overline{\theta}) = 0 \\ \dot{V}^q(\theta; S) = -(1 + \dot{\Lambda}(\theta))\widehat{C}^q_\theta(q^*(\theta), \theta; S) - \Lambda(\theta)\widehat{C}^q_{\theta\theta}(q^*(\theta), \theta; S) \\ V^q(\overline{\theta}; S) \geq 0 \\ U(\theta) = S(e(\theta)) + T(q(\theta)) - C(e(\theta), q(\theta), \theta) \\ V^q(\theta; S) = B^q(q^*(\theta)) - \widehat{C}^q(q^*(\theta), \theta; S) + \Lambda(\theta)\dot{U}(\theta) \end{cases}$$

The program above is conveniently transformed in order to make principal P_q's *ex ante* social welfare and the farmer's informational rent (his profit) appear. By definition of principal P_q's *ex ante* social welfare, we have:

$$V^q(\theta; S) = B^q(q^*(\theta)) - \widehat{C}^q(q^*(\theta), \theta; S) + \Lambda(\theta)\dot{U}(\theta)$$

And, replacing $\widehat{C}^q(q^*(\theta), \theta; S)$ using its definition:

$$V^q(\theta; S) = B^q(q^*(\theta)) - C(e(\theta), q^*(\theta), \theta) + S(e(\theta)) + \Lambda(\theta)\dot{U}(\theta)$$

As the expression of the evolution of the informational rent can alternatively be written as: $\dot{U}(\theta) = -\widehat{C}^e_\theta(e(\theta), \theta; T)$ following equation (6.109), $\dot{U}(\theta)$ can be replaced in the expression above. Hence:

$$S(e(\theta)) = -B^q(q^*(\theta)) + C(e(\theta), q^*(\theta), \theta) + \Lambda(\theta)\widehat{C}^e_\theta(e(\theta), \theta; T) + V^q(\theta; S)$$

Replacing $S(e(\theta))$ by the expression above, P_e's program can be rewritten as follows:

$$\begin{aligned}
&\max_{e(.),V^q(.)} \int_{\underline{\theta}}^{\overline{\theta}} \{B^e(e(\theta)) + B^q(q^*(\theta)) - C(e(\theta), q^*(\theta), \theta) \qquad (6.97)\\
&-\Lambda(\theta)\widehat{C}^e_\theta(e(\theta), \theta; T) - V^q(\theta; S)\} f(\theta) d\theta\\
&s.t. \left\{ \begin{array}{l} \dot{V}^q(\theta; S) = -(1 + \dot{\Lambda}(\theta))\widehat{C}^q_\theta(q^*(\theta), \theta; S) - \Lambda(\theta)\widehat{C}^q_{\theta\theta}(q^*(\theta), \theta; S) \\ \dot{U}(\theta) = -\widehat{C}^e_\theta(e(\theta), \theta; T) \end{array} \right.
\end{aligned}$$

With the specification chosen for the cost function, $\widehat{C}^q_{\theta\theta}(q(\theta), \theta; S)$ can be expressed rather straightforwardly:

$$\begin{aligned}
\widehat{C}^q_{\theta\theta}(q(\theta), \theta; S) &= C_{\theta e}(E(q(\theta), \theta; S), q, \theta)\frac{\partial E}{\partial \theta}(q(\theta), \theta; S) + C_{\theta\theta} \qquad (6.98)\\
&= C_{\theta e}(E(q(\theta), \theta; S), q, \theta)\frac{\partial E}{\partial \theta}(q(\theta), \theta; S)\\
&= \dot{e}(\theta)
\end{aligned}$$

since $C_{\theta e} = 1$.

Upon integrating by parts, the expression $\int_{\underline{\theta}}^{\overline{\theta}} V^q(\theta; S) f(\theta)\, d\theta$ is replaced in principal P_e's maximand. Hence:

$$\begin{aligned}\int_{\underline{\theta}}^{\overline{\theta}} V^q(\theta;S) f(\theta)\, d\theta &= \int_{\underline{\theta}}^{\overline{\theta}} \left\{(1+\dot{\Lambda}(\theta))\widehat{C}^q_\theta(q^*(\theta),\theta;S) + \Lambda(\theta)\widehat{C}^q_{\theta\theta}(q^*(\theta),\theta;S)\right\} F(\theta)d\theta \\ &= \int_{\underline{\theta}}^{\overline{\theta}} \left\{(1+\dot{\Lambda}(\theta))\widehat{C}^e_\theta(e(\theta),\theta;T) + \Lambda(\theta)\dot{e}(\theta)\right\} F(\theta)d\theta\end{aligned}$$

The transition from the second to the third equality is made using $\dot{U}(\theta) = -C_\theta(e(\theta),q(\theta),\theta) = -\widehat{C}^q_\theta(q(\theta),\theta;S) = -\widehat{C}^e_\theta(e(\theta),\theta;T)$ (see appendix B) and $\widehat{C}^q_{\theta\theta}(q^*(\theta),\theta;S) = \dot{e}(\theta)$. Principal P_e's program can finally be rewritten as:

$$\max_{e(.),\dot{e}()} \int_{\underline{\theta}}^{\overline{\theta}} \left\{B^e(e(\theta)) + B^q(q^*(\theta)) - C(e(\theta),q^*(\theta),\theta) - \Lambda(\theta)\widehat{C}^e_\theta(e(\theta),\theta;T)\{2+\dot{\Lambda}(\theta)\} - \Lambda(\theta)^2\dot{e}(\theta)\right\} f(\theta)\, d\theta$$

At this stage, a simplifying assumption is made: the distribution function is the uniform distribution on $\Theta = [0,1]$. The program can thus be rewritten as:

$$\max_{e(.),\dot{e}()} \int_{\underline{\theta}}^{\overline{\theta}} \left\{B^e(e(\theta)) + B^q(q^*(\theta)) - C(e(\theta),q^*(\theta),\theta) - 3\theta\widehat{C}^e_\theta(e(\theta),\theta;T) - \theta^2\dot{e}(\theta)\right\} d\theta$$

Upon integrating $\int_{\underline{\theta}}^{\overline{\theta}} \{\theta^2\dot{e}(\theta)\}d\theta$ by parts, we get:

$$\max_{e(.)} \int_{\underline{\theta}}^{\overline{\theta}} \left\{B^e(e(\theta)) + B^q(q^*(\theta)) - C(e(\theta),q^*(\theta),\theta) - 3\theta\widehat{C}^e_\theta(e(\theta),\theta;T) + 2\theta e(\theta)\right\} d\theta - \overline{\theta}^2 e(\overline{\theta})$$

The first-order condition with respect to e gives the following expression:

$$B^e_e(e^*(\theta)) - C_e(e^*(\theta),q^*(\theta),\theta) - 3\theta\widehat{C}^e_{\theta e}(e^*(\theta),\theta;T) + 2\theta = 0 \tag{6.99}$$

Replacing the "residual" cost function $\widehat{C}^e$ by the "real" cost function C, P_e's first-order condition at the game equilibrium can be written as:

$$B_e^e(e^*(\theta)) - C_e(e^*(\theta), q^*(\theta), \theta) - 3\theta \left\{ C_{\theta e}(e^*(\theta), q^*(\theta), \theta) + \left.\frac{\partial Q}{\partial e}\right|_{(e^*(\theta), q^*(\theta))} C_{\theta q}(e^*(\theta), q^*(\theta), \theta) \right\} + 2\theta = 0$$

For principal P_q, the first-order condition at the game equilibrium is the following (from the previous section in Nash equilibrium):

$$B_q^q(q^*(\theta)) - C_q(e^*(\theta), q^*(\theta), \theta) - \theta \left\{ C_{\theta e}(e^*(\theta), q^*(\theta), \theta) \left.\frac{\partial E}{\partial q}\right|_{(e^*(\theta), q^*(\theta))} + C_{\theta q}(e^*(\theta), q^*(\theta), \theta) \right\} = 0 \tag{6.100}$$

With the simple specifications for the farmer's cost function, the principals' surpluses and the distribution function, the first-order conditions of the regulators' programs may be written as:

$$b^e - (\theta + e^*(\theta) + \beta q^*(\theta)) - 3\theta \left\{ 1 + \frac{\beta \dot{q}^*(\theta)}{\beta \dot{e}^*(\theta) + 1} \right\} + 2\theta = 0 \tag{6.101}$$

$$b^q - (\theta + q^*(\theta) + \beta e^*(\theta)) - \theta \left\{ \frac{\beta \dot{e}^*(\theta)}{\beta \dot{q}^*(\theta) + 1} + 1 \right\} = 0 \tag{6.102}$$

Observe that the solutions for the most efficient agent are the first-best levels. It then remains to solve this differential system.

Lemma 9 *The differential system (approximated for β small) gives the following quantity schedules in the Stackelberg framework under asymmetric information:*

$$\begin{cases} e^{stack}(\theta) = b^e - \beta b^q - 2\theta[1-4\beta] \\ q^{stack}(\theta) = (b^q - \beta b^e) - 2\theta[1-2\beta] \end{cases} \tag{6.103}$$

Proof: see appendix E.

Proposition 10 *The quantities of the environmental good is greater in the Stackelberg framework: $e^{stack}(\theta) \geq e^{nash}(\theta)$, with a strict inequality for $\theta > \underline{\theta}$. The agricultural raw material (good q) has the same production level as in the Nash case, for all θ. The leading principal manages to extract a larger part of the social welfare. The follower extracts a non-zero social welfare (which is a better outcome for her with respect to the perfect information framework). The different quantity schedules are represented on figure (6.8).*

Welfare comparisons show that the Stackelberg leader achieves a higher level of welfare than if she were playing a Nash game (and assuming that the social welfares are evenly distributed between the two regulators. We shall discuss shortly the multiple equilibria problem regarding the Nash outcome). The table below illustrates our point for the subsequent parameters: $\beta = 0.01$ and $b^e = b^q = 15$.

	P_e	P_q	Farmer
Nash	97.19	97.19	13.40
Stackelberg	167.52	26.86	13.43

The transfers and the production costs in the two frameworks under consideration are given below:

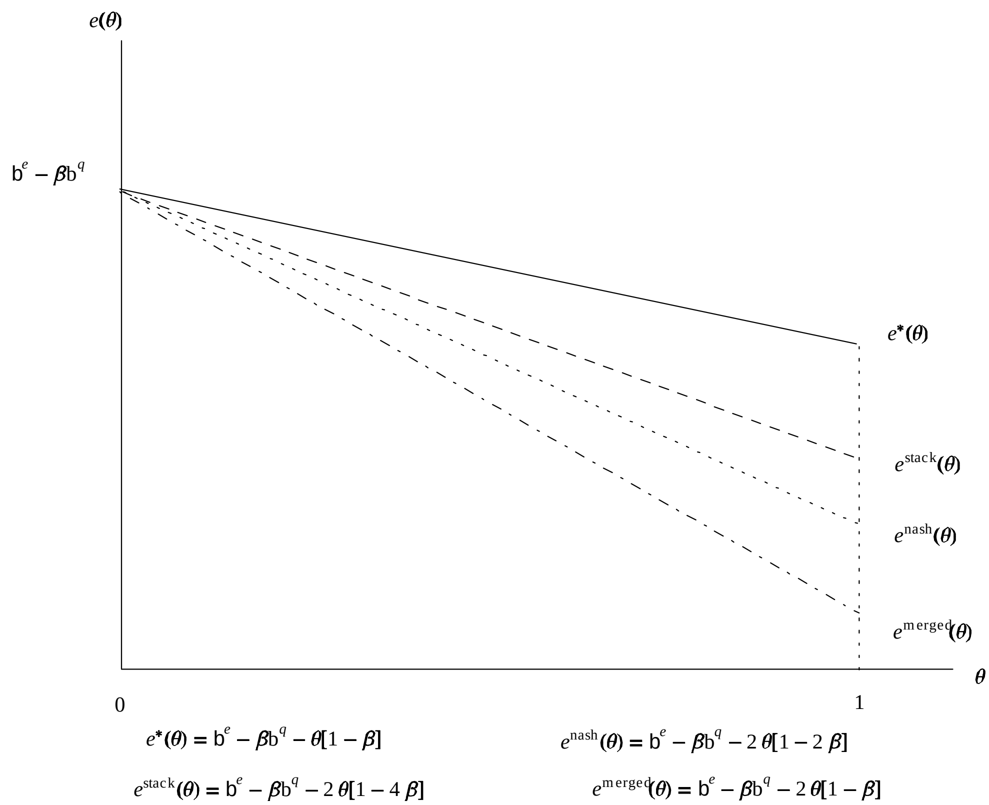

Fig. 6.6. Quantity schedules for the environmental good e under perfect information and in the Nash and Stackelberg frameworks.

	Production cost	$U(\theta)$	$t^e(\theta) + t^q(\theta)$
Nash	208.02	13.4	221.42
Stackelberg	208.60	13.43	222.03

The table below compares the welfare levels of the 3 entities in all the frameworks discussed hitherto. As noted above, the sharing of the social welfare in the Nash settings has been arbitrarily set to $1/2, 1/2$, although these Nash equilibria leave the sharing of the social welfares between the two principals unspecified.

	P_e	P_q	Farmer
Perfect Information, Nash	200.18	200.18	0
Perfect Information, Stackelberg	400.36	0	0
Asymmetric information, Cooperation	97.19	97.19	12.88
Asymmetric information, Nash	97.19	97.19	13.40
Asymmetric information, Stackelberg	167.52	26.86	13.43

First of all, we may note that the Stackelberg setting (be it under perfect or asymmetric information) has the advantage of selecting one equilibrium, while the Nash outcomes were flawed with a multiplicity of equilibria: in the Stackelberg framework, the sharing of the social welfare is unambiguously determined.

Secondly, under asymmetric information, the shifting from a simultaneous contract offer to a setting in which the environmental schedule is first imposed gives (as intuitively expected) a more favorable outcome to the Stackelberg leader, who manages to withhold a more important share of the total social welfare.[81] From a political economy point of view, this means that the pre-eminence of the environmental aspects of the CAP reforms (imposed to the MS who bend towards the interests of

[81] This result was of course all the more true under perfect information.

their agricultural sector) tend to give the European Commission the bigger part of the commonly shared aggregate social welfare.

Finally, comparing the Stackelberg perfect and asymmetric information settings, one can observe that the follower manages to obtain a non-zero social welfare (albeit relatively small) under asymmetric information, whereas she got zero under perfect information. This result may look a bit intriguing at first sight, but it is easily explained: the leading principal, when designing her contractual offer, has to take into account the evolution of the farmers' profit (for the contract to be incentive-compatible): under asymmetric information, the farmer therefore manages to withhold an information rent from both principals. As the following principal's social welfare depends upon the farmer's profit, the leading principal indirectly leaves some social welfare to her follower when focusing on designing an incentive-compatible schedule for her agent. We could say that the follower free rides on the information rent of the farmer.

To sum up, the MS benefits from the informational asymmetry that exist between the two regulators and the farmer. For the MS, the cost of supporting her farmers is diminished thanks to informational asymmetry. The EU, although being the Stackelberg leader, will have to help the MS pay a part of the support she awards to her farmers.

Conclusion

This chapter has striven to study the consequences of the shifting from a Nash to a Stackelberg setting in the contractual offers made from two regulatory entities (agricultural and environmental principals) to farmers. As expected, the environmental regulator gains from playing first. However, the asymmetric information between the regulators and the agricultural sector tends to mitigate the loss of social welfare for the follower, who manages to end up with a non-zero benefit. This framework can apply to various environmental policies for which the regulatory powers are shared between the two levels of regulation. The setting of stringent environmental standards in the latest reforms of the CAP may be linked to the shift in the setting of the game being played between the two regulators, the EU gaining a leadership position.

As the emergence of biofuel policies tend to show, the economic support directed to agriculture will more and more be borne by MS. Hence, the future of agricultural policies will most likely be characterized by re-nationalization. However, this re-nationalization would be only partial, dealing primarily with the economic support to the production of agricultural commodities. The environmental regulation of the agricultural production will still be required, and it seems that the environmental issues are better taken care of at the EU level. Therefore, the question of the competition in the regulation of agriculture between these two entities is bound to emerge in future EU negotiations.

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Appendix

The agent's program second-order conditions (Proof A)

We derive the second-order conditions of the agent's maximization problem. In order to address this question, we need to study the signs of the agent's Hessian matrix, $H(e,q)$. Its expression is the following:

$$H(e,q) = \begin{pmatrix} S_{ee} - C_{ee} & -C_{eq} \\ -C_{qe} & T_{qq} - C_{qq} \end{pmatrix} \tag{6.104}$$

This matrix must be negative semi-definite. The agent's maximization problem is therefore concave if the following conditions are satisfied:

$$\begin{cases} (S_{ee} - C_{ee})(T_{qq} - C_{qq}) - (C_{eq})^2 > 0 \\ S_{ee} - C_{ee} < 0 \\ T_{qq} - C_{qq} < 0 \end{cases} \tag{6.105}$$

Regulator separation. First-order conditions (Proof B)

Following[82] Martimort and Stole (2002) and Salanié (2005), a new cost function which takes account of the agent's optimal behavior facing the contract offered by P_e is introduced. This "residual" cost function vis-à-vis P_q may be written as:[83]

$$\widehat{C}^q(q, \theta; S) = \min_e C(e, q, \theta) - S(e) \tag{6.106}$$

This function determines the cost borne by the $\theta-$type farmer when he produces a quantity q for principal P_q, knowing that he has optimized the quantity $E(q, \theta; S)$ he chooses in the nonlinear schedule offered by P_e and that he has received the payment corresponding to this quantity. We have:[84]

$$E(q, \theta; S) = \arg\min_e C(e, q, \theta) - S(e) \tag{6.107}$$

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[82] Note that appendix B is rigorously identical to the developments conducted in *Chapter 5*. This proof can therefore be skipped by the reader if he has already read section (5.4).

[83] We symmetrically define $\widehat{C}^e(.)$ as:

$$\widehat{C}^e(e, \theta; T) = \min_q C(e, q, \theta) - T(q)$$

[84] Likewise,

$$Q(e, \theta; T) = \arg\min_q C(e, q, \theta) - T(q)$$

Facing the nonlinear schedules offered by the two principals, the agent's problem is the following program. Its maximum is equivalently determined by the three maximization programs below:[85]

$$U(\theta) = \max_{e,q} S(e) + T(q) - C(e,q,\theta) \tag{6.108}$$

$$\begin{aligned} &= \max_{q} T(q) - \widehat{C}^{q}(q,\theta;S) \\ &= \max_{e} S(e) - \widehat{C}^{e}(e,\theta;T) \end{aligned}$$

The solutions $e(\theta)$ and $q(\theta)$ of program (6.108) also verify: $e(\theta) = E(q(\theta),\theta;S)$ and $q(\theta) = Q(e(\theta),\theta;T)$.

By application of the envelope theorem, the incitation constraint of the agent which must be taken into account by both principals can equivalently be written in the three following ways, in relation with the three maximization programs presented above:

$$\dot{U}(\theta) = -C_{\theta}(e(\theta),q(\theta),\theta) = -\widehat{C}^{q}_{\theta}(q(\theta),\theta;S) = -\widehat{C}^{e}_{\theta}(e(\theta),\theta;T) \tag{6.109}$$

Principal P_q solves the following maximization program, which accounts for the agent's participation and incitation constraints.

[85] The second-order conditions of the agent's program are discussed in the appendix.

$$\max_{T(.),q(.)} E_\theta\{B^q(q(\theta)) - T(q(\theta))\}$$
$$s.t. \left\{ \begin{array}{l} \dot{U}(\theta) = -\widehat{C}^q_\theta(q(\theta), \theta; S) \\ U(\theta) \geq 0 \end{array} \right.$$

As $\dot{U}(\theta) = -\widehat{C}^q_\theta(q(\theta), \theta; S) = -C_\theta(e(\theta), q(\theta), \theta) < 0$, the rent function is strictly decreasing in θ. It suffices that the participation constraint be binding in $\overline{\theta}$ to ensure that all types wish to participate. Moreover, as $T(q(\theta)) = U(\theta) + \widehat{C}^q(q(\theta), \theta; S)$, P_q's program can be rewritten as:

$$\max_{q(.),U(.)} \int_{\underline{\theta}}^{\overline{\theta}} \left\{ B^q(q(\theta)) - \widehat{C}^q(q(\theta), \theta; S) - U(\theta) \right\} f(\theta) d\theta$$
$$s.t. \left\{ \begin{array}{l} \dot{U}(\theta) = -\widehat{C}^q_\theta(q(\theta), \theta; S) \\ U(\overline{\theta}) = 0 \end{array} \right. \tag{6.110}$$

By an integration by parts, we may replace $U(\theta)$ by the expression of its derivative in θ, $\dot{U}(\theta)$:

$$\int_{\underline{\theta}}^{\overline{\theta}} U(\theta) f(\theta)\, d\theta = -\int_{\underline{\theta}}^{\overline{\theta}} \dot{U}(\theta) F(\theta)\, d\theta = \int_{\underline{\theta}}^{\overline{\theta}} \widehat{C}^q_\theta(q(\theta), \theta; S) F(\theta)\, d\theta$$

It then remains for principal P_q to solve the following maximization program:

$$\max_{q(.)} \int_{\underline{\theta}}^{\overline{\theta}} \left\{ B^q(q(\theta)) - \widehat{C}^q(q(\theta), \theta; S) - \Lambda(\theta)\widehat{C}^q_\theta(q(\theta), \theta; S) \right\} f(\theta)\, d\theta \tag{6.111}$$

The first-order condition in q gives:

$$B^q_q(q^*(\theta)) - \widehat{C}^q_q(q^*(\theta), \theta; S) - \Lambda(\theta)\widehat{C}^q_{\theta q}(q^*(\theta), \theta; S) = 0 \tag{6.112}$$

A symmetric reasoning for regulator P_e leads to:

$$B_e^e(e^*(\theta)) - \widehat{C}_e^e(e^*(\theta), \theta; T) - \Lambda(\theta)\widehat{C}_{\theta e}^e(e^*(\theta), \theta; T) = 0 \tag{6.113}$$

As $\Lambda(\underline{\theta}) = 0$, the solutions for the most efficient agent correspond to the first-best levels. It remains to replace the "residual" cost function $\widehat{C}_e^e$ (and its derivatives) by the "real" cost function C. This is done following Salanié (2005).

Applying the envelope theorem to program (6.106), the derivatives of these two functions with respect to parameter θ are linked by the following equation.

$$\widehat{C}_\theta^q(q, \theta; S) = C_\theta(E(q, \theta; S), q, \theta) \tag{6.114}$$

Upon derivation with respect to q, we get:

$$\widehat{C}_{\theta q}^q(q, \theta; S) = C_{\theta e}(E(q, \theta; S), q, \theta)\frac{\partial E}{\partial q} + C_{\theta q}(E(q, \theta; S), q, \theta) \tag{6.115}$$

Replacing the "residual" cost functions with the real cost function in the two expressions above gives us:

$$B_q^q(q^*(\theta)) - C_q(e^*(\theta), q^*(\theta), \theta) - \Lambda(\theta)\left\{C_{\theta e}(e^*(\theta), q^*(\theta), \theta)\left.\frac{\partial E}{\partial q}\right|_{(e^*(\theta), q^*(\theta))} + C_{\theta q}(e^*(\theta), q^*(\theta), \theta)\right\} = 0 \tag{6.116}$$

$$B_e^e(e^*(\theta)) - C_e(e^*(\theta), q^*(\theta), \theta) - \Lambda(\theta)\left\{C_{\theta e}(e^*(\theta), q^*(\theta), \theta) + C_{\theta q}(e^*(\theta), q^*(\theta), \theta)\left.\frac{\partial Q}{\partial e}\right|_{(e^*(\theta), q^*(\theta))}\right\} = 0 \tag{6.117}$$

Finally, $\partial E/\partial q$ and $\partial Q/\partial e$ must be replaced. The same path as Salanié (2005) is followed: applying the implicit functions theorem to program (6.106)'s first-order condition, we obtain:

$$S_{ee}\frac{\partial E}{\partial q} = C_{ee}\frac{\partial E}{\partial q} + C_{eq}$$

And, upon rearranging terms:

$$\frac{\partial E}{\partial q} = \frac{C_{eq}}{S_{ee} - C_{ee}}$$

Then, in order to replace S_{ee} in the previous expression, we suppose that an equilibrium of the contract game $(e^*(\theta), q^*(\theta))$ has been reached, and differentiating the agent's first-order condition with respect to θ:

$$S_{ee}(e^*(\theta))\dot{e}^*(\theta) = C_{ee}(e^*(\theta), q^*(\theta), \theta)\dot{e}^*(\theta) + C_{eq}(e^*(\theta), q^*(\theta), \theta)\dot{q}^*(\theta) + C_{e\theta}(e^*(\theta), q^*(\theta), \theta)$$

which gives:

$$S_{ee}(e^*(\theta)) - C_{ee}(e^*(\theta), q^*(\theta), \theta) = \frac{C_{eq}(e^*(\theta), q^*(\theta), \theta)\dot{q}^*(\theta) + C_{e\theta}(e^*(\theta), q^*(\theta), \theta)}{\dot{e^*}(\theta)}$$

and finally:

$$\left.\frac{\partial E}{\partial q}\right|_{(e^*(\theta), q^*(\theta))} = \frac{C_{eq}(e^*(\theta), q^*(\theta), \theta)\dot{e}^*(\theta)}{C_{eq}(e^*(\theta), q^*(\theta), \theta)\dot{q}^*(\theta) + C_{e\theta}(e^*(\theta), q^*(\theta), \theta)}$$

The expression of $\frac{\partial Q}{\partial e}$ is obtained in a symmetric way:

$$\left.\frac{\partial Q}{\partial e}\right|_{(e^*(\theta),q^*(\theta))} = \frac{C_{eq}(e^*(\theta),q^*(\theta),\theta)\dot{q}^*(\theta)}{C_{eq}(e^*(\theta),q^*(\theta),\theta)\dot{e}^*(\theta)+C_{q\theta}(e^*(\theta),q^*(\theta),\theta)}$$

With the specified functions presented above, we get:

$$\begin{cases} b^e-(\theta+e^*(\theta)+\beta q^*(\theta))-\Lambda(\theta)\left\{1+\frac{\beta\dot{q}^*(\theta)}{\beta\dot{e}^*(\theta)+1}\right\}=0 \\ b^q-(\theta+q^*(\theta)+\beta e^*(\theta))-\Lambda(\theta)\left\{\frac{\beta\dot{e}^*(\theta)}{\beta\dot{q}^*(\theta)+1}+1\right\}=0 \end{cases} \tag{6.118}$$

Nash under asymmetric information: approximation of quantity schedules (Proof C)

Taking $\beta \simeq 0$, the differential system can be conveniently simplified:

$$b^e-(\theta+e(\theta)+\beta q(\theta))-\theta\left\{1+\beta\dot{q}(\theta)\right\}=0 \tag{6.119}$$

$$b^q-(\theta+q(\theta)+\beta e(\theta))-\theta\left\{1+\beta\dot{e}(\theta)\right\}=0 \tag{6.120}$$

Differentiating equation (6.120) with respect to θ,we get:

$$-1-\dot{q}(\theta)-\beta\dot{e}(\theta)-1-\beta\dot{e}(\theta)-\theta\beta\ddot{e}(\theta)=0 \tag{6.121}$$

Hence, $\dot{q}(\theta)$ can be expressed in the following way:

$$\dot{q}(\theta)=-2-2\beta\dot{e}(\theta)-\theta\beta\ddot{e}(\theta) \tag{6.122}$$

Rewriting (6.120), $q(\theta)$ takes the subsequent expression:

$$q(\theta)=b^q-\theta-\beta e(\theta))-\theta\left\{1+\beta\dot{e}(\theta)\right\} \tag{6.123}$$

And, replacing $q(\theta)$ and $\dot{q}(\theta)$ in the equation (6.119):

$$b^e - (\theta + e(\theta) + \beta q(\theta)) - \theta\left\{1 + \beta\dot{q}(\theta)\right\} = 0 \tag{6.124}$$

$$b^e - 2\theta - e(\theta) - \beta[b^q - \theta - \beta e(\theta)) - \theta\left\{1 + \beta\dot{e}(\theta)\right\}] - \theta\beta[-2 - 2\beta\dot{e}(\theta) - \theta\beta\ddot{e}(\theta)] = 0 \tag{6.125}$$

Neglecting the terms in β^2, we finally obtain:

$$e^{nash}(\theta) = b^e - \beta b^q - 2\theta[1 - 2\beta] \tag{6.126}$$

And, after replacing $e(\theta)$ in equation (6.120)

$$q^{nash}(\theta) = (b^q - \beta b^e) - 2\theta[1 - 2\beta] \tag{6.127}$$

Which gives the result.

Stackelberg perfect information framework (Proof D)

The first-order conditions can conveniently be stated using the simple specifications we have already used in the Nash framework.

For all θ, the two goods are produced at their first-best levels:

$$\left\{ \begin{array}{l} b^e = \theta + e^F(\theta) + \beta q^F(\theta) \\ b^q = \theta + q^F(\theta) + \beta e^F(\theta) \end{array} \right. \tag{6.128}$$

The resolution of this system is straightforward and leads to:

$$\left\{ \begin{array}{l} e(\theta) = \frac{b^e - \beta b^q - \theta(1-\beta)}{1-\beta^2} \\ q(\theta) = \frac{b^q - \beta b^e - \theta(1-\beta)}{1-\beta^2} \end{array} \right. \tag{6.129}$$

We derive the transfers from both principals to the agent, using the fact that both the agent and principal P_q are maintained at their reservation utility levels, i.e. zero.

P_q's utility level set at zero allows to derive the transfers $\{t(\theta)\}_{\theta\in\Theta}$:

$$t(\theta) = b^q q(\theta) = b^q \left(\frac{b^q - \beta b^e - \theta(1-\beta)}{1-\beta^2} \right)$$

And the agent's zero utility level enables us to derive P_e's payments $\{s(\theta)\}_{\theta\in\Theta}$.

$$s(\theta) + t(\theta) - C(e(\theta), q(\theta), \theta) = 0$$

$$s(\theta) = C(e(\theta), q(\theta), \theta) - t(\theta)$$

$$\begin{aligned} s(\theta) \quad = \quad & \theta \left\{ \left(\frac{b^e - \beta b^q - \theta(1-\beta)}{1-\beta^2} \right) + \left(\frac{b^q - \beta b^e - \theta(1-\beta)}{1-\beta^2} \right) \right\} \\ & + \frac{1}{2} \left\{ \left(\frac{b^e - \beta b^q - \theta(1-\beta)}{1-\beta^2} \right)^2 + \left(\frac{b^q - \beta b^e - \theta(1-\beta)}{1-\beta^2} \right)^2 \right\} \\ & + \beta \left(\frac{b^e - \beta b^q - \theta(1-\beta)}{1-\beta^2} \right) \left(\frac{b^q - \beta b^e - \theta(1-\beta)}{1-\beta^2} \right) \\ & - b^q \left(\frac{b^q - \beta b^e - \theta(1-\beta)}{1-\beta^2} \right) \end{aligned}$$

Taking the simplest case where the principals' marginal surpluses are chosen equal: $b^e = b^q = b$, with $b > \theta$, $\forall\ \theta$, we therefore have the symmetric production levels:

$$e(\theta) = q(\theta) = \frac{b-\theta}{1+\beta}$$

And the principals' transfers to the agent take the following expressions:

$$t(\theta) = bq(\theta) = b\left(\frac{b-\theta}{1+\beta}\right)$$

and

$$s(\theta) = \frac{\theta(b-\theta)}{1+\beta}$$

Stackelberg under asymmetric information: approximation of quantity schedules (Proof E)

Taking $\beta \simeq 0$, the differential system can be conveniently simplified:

$$b^e - (\theta + e(\theta) + \beta q(\theta)) - 3\theta\left\{1 + \beta\dot{q}(\theta)\right\} + 2\theta = 0 \tag{6.130}$$

$$b^q - (\theta + q(\theta) + \beta e(\theta)) - \theta\left\{1 + \beta\dot{e}(\theta)\right\} = 0 \tag{6.131}$$

Differentiating equation (6.131) with respect to θ,we get:

$$-1 - \dot{q}(\theta) - \beta\dot{e}(\theta) - 1 - \beta\dot{e}(\theta) - \theta\beta\ddot{e}(\theta) = 0 \tag{6.132}$$

Hence, $\dot{q}(\theta)$ can be expressed in the following way:

$$\dot{q}(\theta) = -2 - 2\beta\dot{e}(\theta) - \theta\beta\ddot{e}(\theta) \tag{6.133}$$

Rewriting (6.131), $q(\theta)$ takes the subsequent expression:

$$q(\theta) = b^q - \theta - \beta e(\theta)) - \theta \{1 + \beta \dot{e}(\theta)\} \tag{6.134}$$

And, replacing $q(\theta)$ and $\dot{q}(\theta)$ in the equation (6.130):

$$b^e - (\theta + e(\theta) + \beta q(\theta)) - 3\theta \{1 + \beta \dot{q}(\theta)\} + 2\theta = 0 \tag{6.135}$$

$$b^e - 2\theta - e(\theta) - \beta[b^q - \theta - \beta e(\theta)) - \theta \{1 + \beta \dot{e}(\theta)\}] - 3\theta\beta[-2 - 2\beta \dot{e}(\theta) - \theta\beta \ddot{e}(\theta)] = 0 \tag{6.136}$$

Neglecting the terms in β^2, we finally obtain:

$$e^{stack}(\theta) = b^e - \beta b^q - 2\theta[1 - 4\beta] \tag{6.137}$$

And, after replacing $e(\theta)$ in equation (6.131)

$$q^{stack}(\theta) = (b^q - \beta b^e) - 2\theta[1 - 2\beta] \tag{6.138}$$

Which gives the result.

Sufficient condition to have a strictly decreasing profit function for the follower $[\dot{V}^q(\theta; S) < 0]$ (Proof F)

We look for a sufficient condition to have

$$\frac{dV^q(\theta; S)}{d\theta} = -(1 + \dot{\Lambda}(\theta))\widehat{C}^q_\theta(q^*(\theta), \theta; S) - \Lambda(\theta)\widehat{C}^q_{\theta\theta}(q^*(\theta), \theta; S) < 0 \tag{6.139}$$

We must have : $-2(e(\theta) + q(\theta)) - \theta \dot{e}(\theta) < 0$.

replacing $\dot{e}(\theta)$ using (6.131), we get:

$$
\begin{aligned}
-2(e(\theta)+q(\theta))-\theta\frac{b^q-2\theta-q(\theta)-\beta e(\theta)}{\theta\beta} &< 0 \qquad (6.140)\\
-2\beta e(\theta)-2\beta q(\theta)-b^q+2\theta+q(\theta)+\beta e(\theta) &< 0
\end{aligned}
$$

$$b^q > 2\theta+(1-2\beta)q(\theta)-\beta e(\theta)$$

It therefore suffices to choose b^q large enough.

Discussion on the definition of the profit chosen for the principal

In this section we discuss the two alternative definitions of a principal's profit in her relationship with a $\theta-$type agent:

- Let $\pi(\theta)$ be the profit achieved *ex post* with an agent of type θ, when the contract between the principal and the agent is realized.

  We have

$$
\begin{aligned}
\pi(\theta) &= B(e(\theta))-t(\theta) \qquad (6.141)\\
&= B(e(\theta))-C(e(\theta),\theta)-U(\theta)\\
&= B(e(\theta))-C(e(\theta),\theta)-\int_{\theta}^{\overline{\theta}}C_x(e(x),x)dx
\end{aligned}
$$

- In contrast, let $V(\theta)$ be the net economic profit that the principal considers *ex ante* before to offer a contract to a $\theta-$type agent.This seems to be the more economically appealing profit since it takes into account the productive efficiciency of the relationship with agent θ on the one hand and the cost of the informational rents given away to more efficient agents on the other hand. $V(\theta)$ is defined by:

$$V(\theta) = B(e(\theta)) - C(e(\theta), \theta) - \frac{F(\theta)}{f(\theta)} C_\theta(e(\theta), \theta) \tag{6.142}$$

Of course, these two alternative definitions of profits have equal expectations:

$$E_\theta \pi(\theta) = E_\theta V(\theta) \tag{6.143}$$

This claim is proven straightforwardly:

$$\begin{aligned}
E_\theta \pi(\theta) &= \int_{\underline{\theta}}^{\overline{\theta}} \pi(\theta) f(\theta) d\theta = \int_{\underline{\theta}}^{\overline{\theta}} \{B(e(\theta)) - C(e(\theta), \theta) - U(\theta)\} f(\theta) d\theta \\
&= \int_{\underline{\theta}}^{\overline{\theta}} \{B(e(\theta)) - C(e(\theta), \theta) - \left(\int_{\theta}^{\overline{\theta}} C_x(e\left(x\right), x) dx \right) \} f(\theta) d\theta \\
&= \int_{\underline{\theta}}^{\overline{\theta}} \left\{ B(e(\theta)) - C(e(\theta), \theta) - \frac{F(\theta)}{f(\theta)} C_\theta(e(\theta), \theta) \right\} f(\theta) d\theta \\
&= E_\theta V(\theta)
\end{aligned}$$

While first-generation biofuels are obtained from storage organs, second-generation biofuels are produced froms lignocellulose, which is the main building block of vegetal cell walls. There are two technologies to transform lignocellulose into second-generation biofuels: thermochemical or biochemical conversion. It seems noteworthy to give some basic explanations about the technical differences between the two ways of conversion, since the economic situation resulting from the adoption of either tecchnology will be quite different. **The thermochemical conversion** The thermochemical conversion consists in breaking up molecules by the action of temperature in various physico-chemical conditions. This method of transformation aims at converting the cellulosic biomass into two elementary gases, carbon monoxide (CO) and hydrogen ($H2$). This gaseous mix, referred to as syngas, is then purified and used to synthetize liquid fuels, notably through Fischer-Tropsch synthesis. The quality of the lignocellulosic raw material is crucial for the thermochemical conversion: the variability of the mineral and water contents constitutes the major hurdle for this type biomass conversion. A wide array of fuels can be obtained through Fischer-Tropsch synthesis: they are identical to fossil hydrocarbures. **The biochemical conversion** The biochemical conversion technology (also referred to as biological conversion) aims at producing one type of biofuel principally: ethanol. This transformation rests on biochemical processes (conversions thanks to microorganisms and enzymes) ; it also involves physico-chemical processes. The biochemical conversion consists in breaking down the lignocellulosic biomass into elementary organic molecules, most notably into simple sugar molecules, which can be thereafter converted into ethanol by fermentation. Just as in the thermochemical conversion, the composition of the lignocellulosic raw material represents one of the major constraints of its conversion through the biochemical conversion. However, all kinds of biomass share the presence of 3 majors macromolecular compounds: cellulose, hemicellulose and lignins. Cellulose is a linear polymer made up of glucose, a 6-carbons sugar which can be transformed into ethanol by numerous microorganisms. Hemicelluloses are sugar heteropolymers whose monomers are made up most often of 5 carbon atoms, sometimes 6. Hemicelluloses therefore represent a potentially significant source of fermentiscible sugars. However, even if many bacterian and fungus microorganisms can metabolize those sugars, their fermentation into ethanol is a much rarer path. Lignins are complex heteropolymers whose monomers derive from 3 alcools with phenolic cycle. Some microorganisms are able to catabolize these sugars naturally, but with a very low yield which prevents to imagine any industrial development.

Box 10: The two possible technologies for the second generation of biofuels. This is adapted from an article by Gosse, G. et al., entitled "La seconde génération de biocarburants", published in the Biofuel Survey under the supervision of Tréguer, D., Déméter 2008, 352 pp.

General Conclusion

This dissertation has striven to analyze the main economic problems linked to biofuel policies. More precisely, this thesis has attempted to enlighten the strong links that exist between biofuel and agricultural policies. First and foremost, the central role of the State in the development of biofuel policies has been stressed in the *first part* of this thesis. Indeed, biofuel development rests on a strong commitment from the State, which translates into the enforcement of incentives (subsidies and mandatory blending mainly) aimed at ensuring the production of a desired quantity of biofuels. Owing to the sizeable budgetary cost of biofuel subsidies, the support directed to biofuels slowly evolves towards mandatory blending policies, which transfers the burden of biofuel support from taxpayers to consumers. The objectives put forward by the states to justify the development of biofuels are numerous (e.g. security of supply, GHG emission reduction, rural development, etc.). However, the main objective of biofuel policies boils down to agricultural income concerns, as the simple welfare analyses led in *Chapter 1* have shown. The tight link between biofuel policies and the support to farmers income is further demonstrated in the case of France in *Chapter 2:* the justifications of biofuel policies as energy policies appear particularly weak. Besides, the analysis conducted for France shows that biofuel producers have benefited from very high subsidies, far more than what was necessary to break even.

The *second part* of the dissertation has investigated the close links between biofuel policies and the present CAP (*Chapters 3 & 4).* The next reforms of the

CAP will need to integrate the new central position held by biofuels. Thus, *Chapter 3* has studied the possible substitutions between traditional decoupled payments and the new support for biofuel policies. The main result reached in our analysis is that it might be welfare-improving to move from an agricultural policy which transfers decoupled payments to the farmers towards a policy in which the decoupled payments would have been reduced, partially substituted for by the support to biofuel (either subsidies or mandatory blending schemes). This result rests on the hypothesis that the distortions in the economy are sufficiently high. We have no clear indication yet that the next reform of the Common Agricultural Policy will follow that trail. Nevertheless, it seems obvious that biofuel policy offers a new economic support to the agricultural sector, which therefore benefits from a dual support.

Besides, biofuel production is likely to put an increased pressure on the environment, since it triggers price hikes. The environmental regulation concerning the agricultural production ought to take this new framework into account. The model developed in *Chapter 4* shows the problems facing the regulators for enforcing environmental policies in agriculture. While the latest reforms of the CAP had evolved towards the setting of stringent environmental standards, biofuel policies raise issues regarding the enforcement of these standards: if the scenario of a decrease in the level of decoupled payments materializes, the penalties in the framework of cross-compliance (a fraction of the Single Farm Payment) will lose their role as credible deterrents. Hence, we show that a fixed penalty would be more efficient than a fraction of the decoupled payment in this new biofuel setting.

While the *second part* of this dissertation modelled the agricultural sector as a representative farmer, the *third part* explicitely takes into account the heterogeneity of the agricultural sector. *Chapter 5* has exposed a framework well-suited to consider the duality of agricultural production, under asymmetric information: Common Agency theory. Finally, *Chapter 6* has striven to model the competition between two levels of regulation: the EU and the Member State (MS) levels, in the case where one regulator is a Stackelberg leader. In the setting where the EU is the Stackelberg leader, we show that the introduction of an informational asymmetry between the farmer and his regulator ends up to a situation in which the follower manages to withhold a benefit, while the perfect information setting leaves him with a zero benefit. Hence, even if the Stackelberg leader (in our model, the EU) manages to extract the bigger part of the social benefit, the follower nevertheless ends up with a non-zero benefit thanks to informational asymmetry. The MS benefits from the informational asymmetry that exist between the two regulators and the farmer. For the MS, the cost of supporting her farmers is diminished thanks to informational asymmetry. Should future reforms of the Common Agricultural Policy evolve towards re-nationalization after 2013, it seems highly possible that the EU Commission will keep the environmental regulation in its grasp. Hence, the question of the consequences of regulation separation between the EU and the MS (the EU regulator being the leader) might well become a lively issue in the future.

Finally, it seems worth stressing that biofuel policies are nothing more than policies bearing a close link with agricultural policies. Touting biofuels as the universal solution to the GHG emissions in the transport sector has been overused by their promotors, who are experimenting today a powerful backlash as evidence grows that biofuels record concerning GHG emissions are not so good (even negative when taking account of the land use changes, cf Searchinger *et al.* and Fargione *et al.*, 2008) and their responsibility in the recent price hike in agricultural markets might be sizeable (according to a recent unpublished report from the World Bank). Hence, handing out large amount of subsidies for biofuel production (or, equivalently, setting up mandates) seems a misguided policy. It is high time that these policies be ground to a halt. A moratorium on biofuels would help take the time for a thorough reflection on the implications of biofuel production (such a reflection should have been carried out before launching large biofuel programs).

Synthèse

L'objectif de cette thèse est d'étudier les politiques de promotion des biocarburants sous l'angle de l'économie publique. Plus précisément, son but est d'éclairer les liens très étroits qui existent entre les politiques de biocarburants et les réformes de la Politique Agricole Commune (PAC), passées, présentes et à venir. Au début simple mesure liée à la réforme de la PAC de 1992 (la mise en place d'une jachère obligatoire avait permis la production de cultures énergétiques sur cette terre interdite aux productions alimentaires), les biocarburants se sont récemment affirmés comme une composante essentielle de l'agriculture européenne. En effet, bien que les politiques de biocarburants ne soient pas formellement un élément de la PAC, les répercussions qu'elles engendrent sur les marchés agricoles créent de fait un lien très étroit avec la PAC. L'étude des liens des politiques de biocarburants avec les différentes réformes de la PAC constitue le fil conducteur de cette thèse.

Il convient avant tout de rappeler ce que sont les biocarburants : il s'agit de substituts aux carburants d'origine fossile obtenus à partir d'une matière première d'origine végétale. L'éthanol (obtenu à partir de plantes sucrières comme la canne ou la betterave à sucre ou de l'amidon de céréales : blé, maïs, orge...) remplace l'essence et le biodiesel (obtenu par estérification d'une huile végétale de colza, soja, palme, tournesol ou coton avec un alcool, le méthanol principalement) remplace le diesel. Les politiques de biocarburants sont mises en place à l'initiative des Etats, qui assurent la production de biocarburants par le biais de subventions (ou, de manière équivalente, de défiscalisation partielle des droits d'accise s'appliquant aux biocarburants) ou de mécanismes d'incorporation obligatoire. Sans ces mesures de soutien décidées par les Etats, la production de biocarburants ne serait pas viable.[86] Ces politiques sont souvent justifiées par les avantages économiques qui leur seraient associées : lutte contre les émissions de gaz à effet de serre dans les transports,[87] emploi rural, sécurité énergétique, etc. Toutefois, leur intérêt très fort comme instruments de soutien des revenus agricoles (via la hausse des prix des matières premières agricoles) n'est généralement pas mis en avant. L'Union Européenne (UE) n'a ainsi jamais explicitement retenu cet objectif pour justifier sa politique de biocarburants. Pourtant, force est de constater que les politiques de biocarburants ne sont compréhensibles qu'à travers le prisme des politiques agricoles.

Cette thèse s'articule autour de trois parties, qui visent chacune à éclairer sous un angle différent les liens entre les politiques de biocarburants et les évolutions de la PAC.

Dans une première partie, les politiques de biocarburants mises en place par les différents Etats Membres de l'UE seront détaillées. De plus, les raisons de l'émergence des politiques de biocarburants dans l'UE sera expliquée (*Chapitre 2)*. En outre, la production de biocarburants sera comparée aux "anciennes" politiques agricoles, antérieures à la réforme du début des années 90.

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[86] Ainsi, même au Brésil, la production de biocarburants n'a été rentable que quelques mois au cours de l'année 2005. Le reste du temps, les défiscalisations mises en place par l'Etat fédéral et les Etats producteurs s'avèrent nécessaires (ESMAP, 2007).

[87] Deux articles publiés en Février 2008 dans la revue *Science :* Searchinger *et al.* et *Fargione et al.* remettent sérieusement en cause les bilans positifs attribués aux biocarburants en matière d'émission de gaz à effet de serre.

Dans une seconde partie, les conséquences de la production actuelle de biocarburants sur les prix des matières premières agricoles seront prises en compte afin de réfléchir aux évolutions possible de la PAC actuelle, à la fois en termes de soutiens aux agriculteurs (*Chapitre 3*) que du respect des politiques de conditionnalité (et notamment d'éco-conditionnalité, *Chapitre 4*).

Enfin, la dernière partie propose un nouveau cadre théorique de régulation pour l'agriculture européenne, dans lequel deux niveaux de régulation (l'UE et les différents Etats Membres) contrôlent chacun un bien produit par un agriculteur. L'UE[88] s'intéresse au bien environnemental (e.g. l'effort de réduction d'émissions polluantes), les Etats Membres possédant un secteur agricole important sont pour leur part intéressés par la production de commodités agricoles afin d'augmenter le revenu de leurs agriculteurs. Ce cadre théorique vise à formaliser le dilemme auquel est confrontée l'agriculture, qui produit des commodités agricoles en quantités importantes (du fait des prix élevés) et doit également respecter les dispositions environnementales qui ont été intégrées dans la PAC. Ainsi, la théorie de l'Agence Commune sera mobilisée pour cette partie. Contrairement à la partie II dans laquelle nous étudions le comportement d'un agriculteur représentatif, nous prenons explicitement en compte l'hétérogénéité du secteur agricole, ainsi que l'asymétrie d'information existant entre les agriculteurs et leurs régulateurs. Cette partie vise également à anticiper la PAC de l'après-2013, et une possible re-nationalisation d'une grande partie des aides attribuées aux agricul-

[88] Les Etats Membres ne possédant pas un secteur agricole important et/ou attachant une grande importance au respect de l'environnement sont considérés comme ayant des objectifs parfaitement alignés sur ceux de la Commission Europénne.

teurs. Dans ce cas de figure extrême, la régulation environnementale continuerait d'être décidée au niveau de l'UE, alors que les Etats-Membres choisiraient le montant du soutien qu'ils désirent accorder à leurs agriculteurs. L'étude des interactions entre ces deux niveaux de régulation fera l'objet du *Chapitre 6,* le *Chapitre 5* étant pour sa part destiné à présenter le cadre théorique de l'Agence Commune.

Partie I

Le *Chapitre 1* présente les deux principaux instruments utilisés pour promouvoir la production des biocarburants : la défiscalisation partielle des droits d'accise et l'incorporation obligatoire.

- La défiscalisation partielle des droits d'accises est équivalente à une subvention octroyée aux biocarburants et est donc supportée par les contribuables.

- L'incorporation obligatoire consiste à remplacer une partie des carburants d'origine fossile par des biocarburants. Le surcoût (les biocarburants coûtant plus cher que les carburants pétroliers auxquels ils se substituent) est payé par les consommateurs.

Par ailleurs, ce premier chapitre détaille le cadre hétérogène du développement des biocarburants au sein de l'UE. L'UE a fixé des objectifs (non contraignants) de 5,75% d'incorporation de biocarburants dans les carburants utilisés pour les transports terrestres en 2010, mais laisse les Etats Membres (EM) libres de décider des objectifs entre types de biocarburants (parts respectives de biodiesel et d'éthanol) ainsi que des instruments économiques à mettre en place pour permettre la production effective de biocarburants.

Enfin, le *Chapitre 1* vise à souligner des points communs entre les politiques de biocarburants et les "anciennes" politiques agricoles qui étaient en place jusqu'à la fin des années 80. Ces politiques consistaient à garantir un prix élevé aux producteurs. Elles ont depuis été réformées en profondeur, évoluant vers des politiques de paiements découplés. La production de biocarburants représente une demande supplémentaire adressée au secteur agricole, qui provoque une augmentation des prix. Les effets en termes de bien-être pour les différents agents de l'économie sont comparés à ceux des "anciennes" politiques agricoles.

Le *Chapitre 2* rappelle que la production de biocarburants a débuté à la faveur d'une disposition contenue dans la réforme de la PAC de 1992, qui prévoyait l'instauration d'une jachère obligatoire afin de réguler l'offre agricole (en situation de surproduction). La production de cultures énergétiques était autorisée sur ces terres gelées pour la production alimentaire. Les cultures énergétiques constituaient une solution *ad-hoc* intéressante pour accompagner cette réforme importante de la PAC. Le colza ester avait été préféré aux autres cultures énergétiques car, en raison de son faible rendement, il permettait de couvrir la surface maximale de jachère pour une enveloppe budgétaire donnée. Cette réforme de 1992 marquait la première étape d'une mutation de la PAC d'un système de soutien aux prix à un soutien aux revenus. Ce chapitre vise à étudier le cadre de la production de biocarburants existant avant les programmes de développement mis en place en 2004-2005. A l'aide d'un modèle d'équilibre partiel développé par l'INRA, nous étudions la répartition des surplus entre les divers acteurs de la filière biocarburants. Ainsi, il apparaît que le gain des agriculteurs est modeste par rapport au gain de l'industrie de transformation des biocarburants. En outre, ce chapitre met en avant le caractère insuffisant de l'externalité CO_2 pour justifier les soutiens économiques conséquents dont bénéficient les filières de biocarburants. Enfin, l'accent est mis sur les problèmes méthodologiques dans le calcul des bilans énergétiques des biocarburants, notamment en ce qui concerne l'utilisation des co-produits. Pour conclure, nous montrons que les politiques de biocarburants sont nées grâce à une disposition contenue dans la réforme de la PAC de 1992, et sont avant tout un mode de soutien à l'agriculture, et non de nouvelles filières énergétiques aptes à rivaliser avec la filière pétrolière.

Partie II

Les politiques actuelles en faveur des biocarburants ne peuvent s'expliquer sans prendre en compte les interactions entre celles-ci et les politiques agricoles, bien qu'il n'y ait pas formellement de lien entre la PAC et les politiques de biocarburants. L'apparition d'une nouvelle demande pour les productions agricoles a pour conséquence une augmentation sensible du prix des commodités agricoles. Ce chapitre présente plusieurs études qui évaluent l'impact des programmes de biocarburants sur les prix des matières premières agricoles. La plupart des programmes de développement des biocarburants ont été initiés sous la pression des lobbies agricoles qui considèrent les biocarburants comme un nouveau débouché capable d'endiguer la baisse des revenus agricoles. L'émergence des politiques de soutien aux biocarburants pose le problème d'un soutien au secteur agricole (au sens large) qui est double : d'une part, l'Etat verse des paiements découplés aux agriculteurs (Droit à Paiement Unique, mis en place en janvier 2006 en France), d'autre part, l'Etat soutient les industries de biocarburants, dont les coûts de production excèdent la valorisation des biocarburants. En raison du poids important de la PAC dans le budget de l'UE et de la coexistence de la PAC et des politiques en faveur des biocarburants, se pose la question de la possibilité d'une substitution partielle des aides PAC par les subventions aux biocarburants, et donc d'un transfert du financement des politiques agricoles de l'UE vers les Etats membres. Aux Etats-Unis, le programme éthanol qui a permis une hausse sensible du prix du maïs a d'ores et déjà opéré cette substitution: même s'ils n'ont pas été supprimés d'un point de vue légal, les paiements contra-cycliques n'ont pas été déclenchés lors des dernières récoltes. Pour un objectif de revenu agricole fixé, l'Etat pourrait ainsi opérer une substitution partielle entre soutien au revenu agricole et soutien aux industries de transformation de biocarburants.

Pour répondre à cette question, nous avons développé une analyse de la compétition entre usages alimentaires et énergétiques des productions agricoles. Résumons-en les principales caractéristiques. Il s'agit d'un modèle faisant intervenir les différentes parties prenantes du dossier : l'Etat, le secteur agricole, les industries de transformation des biocarburants et les industries agro-alimentaires. L'Etat s'est engagé à développer le secteur des biocarburants, tout en maintenant un revenu garanti au secteur agricole. La hausse des revenus agricoles permise par l'augmentation du prix des commodités permet à l'Etat de diminuer le paiement découplé agricole, tout en assurant un revenu seuil aux agriculteurs. Dans une première approche, l'Etat possède toute l'information nécessaire à l'ajustement de la subvention minimale nécessaire aux industries des biocarburants pour que la production puisse se faire.

Par ailleurs, pour tenir compte de la contrainte budgétaire de l'Etat, un facteur $(1+\lambda)$ est affecté aux subventions accordées par l'Etat, λ étant le coût d'opportunité des fonds publics, qui résulte des distorsions dans l'économie liées aux impôts levés pour pouvoir distribuer ces subventions.

Le principal résultat de ce chapitre est que l'Etat a intérêt à mettre en place une production de biocarburants, en dehors de tout intérêt environnemental, car une redistribution de revenu va s'opérer entre le secteur agro-alimentaire (dont les profits vont s'éroder) et les agriculteurs (qui voient le produit de leurs ventes augmenter). Pour assurer un niveau de revenu donné aux agriculteurs, l'Etat va pouvoir diminuer son enveloppe globale de subventions (au secteur de la transformation de biocarburants et aux agriculteurs directement sous forme de paiements découplés), et il y aura donc globalement une baisse des distorsions dans l'économie. Ceci est principalement dû au fait que le secteur agro-alimentaire (et les consommateurs de produits alimentaires) va payer le surcoût de la matière première agricole : les contribuables gagneraient à ce changement de politique, les consommateurs et l'agro-industrie y perdraient. Bien entendu, ce résultat repose entièrement sur l'existence de telles distorsions dans l'économie à un niveau suffisamment important, i.e. il faut que le coût d'opportunité des fonds publics soit plus grand qu'une valeur seuil pour que la quantité de biocarburants à produire soit strictement positive.

Ensuite, les politiques de biocarburants posent un problème pour la pérennité des dispositifs environnementaux contenus dans la PAC. Remarquons tout d'abord qu'il y a une contradiction dans les termes entre le respect d'un objectif ambitieux de production de biocarburants, qui pousse (via le signal prix) à l'obtention de rendements élevés et donc à une intensification de la production agricole et l'adoption de pratiques agricoles respectueuses de l'environnement.

Le *Chapitre 4* présente d'abord des dispositions environnementales liées à la PAC et met en avant le problème de la mise en application et du respect des standards environnementaux.

Avec la transition progressive d'un soutien par les prix à un soutien au revenu, la PAC avait opéré un renforcement concomitant des politiques de protection de l'environnement dans la production agricole. Ainsi, les aides découplées versées aux agriculteurs sont progressivement devenues conditionnelles, et notamment éco-conditionnelles (respect d'un certain nombre de directives européennes de protection de l'environnement). L'objectif des paiements découplés est double : d'une part, garantir un revenu minimum aux agriculteurs, d'autre part, s'assurer que la production agricole s'inscrit dans un cadre de bonne pratiques agronomiques et environnementales. Le versement d'un paiement découplé étant subordonné au respect de ces bonnes pratiques, le régulateur peut infliger une pénalité d'un montant inférieur ou égal au paiement découplé, et ne peut aller au-delà.[89]

Si les aides aux biocarburants se substituent partiellement aux aides agricoles découplées, la conditionnalité perdra une partie de sa justification, de sa crédibilité et de son efficacité. Quels garde-fous pourraient alors être mis en place pour empêcher la production intensive de cultures à vocation énergétique, favorisée par l'attrait de cours élevés des matières agricoles ? Les aides découplées résiduelles ne seront plus le moyen unique de garantir un revenu aux agriculteurs (le soutien aux filières de biocarburants aura partiellement pris le relais). Continueront-elles à remplir leur rôle de garant de bonnes pratiques environnementales, alors même qu'elles seront diminuées et donc (en supposant que leur non versement est la pénalité maximale infligeable en cas de non-respect) perdront une partie de leur effet incitatif? Le paiement découplé (toujours conditionné à de bonnes pratiques environnementales) serait-il encore l'instrument adapté, sachant que l'incitation au non-respect de ces pratiques (évasion) grandira avec le niveau du cours des commodités agricoles en même temps que la pénalité maximale diminuera? Pour conserver un même niveau d'objectif environnemental, il faudrait prévoir un renforcement des instruments, soit en augmentant la fréquence des contrôles (ce qui augmentera bien entendu le coût total du contrôle) et/ou en augmentant la pénalité infligée en cas de fraude, en lui permettant de prendre une valeur supérieure au paiement découplé non versé. Si la fréquence des contrôles n'augmente pas, il faudra alors accepter d'abaisser le niveau de

[89] Dans la pratique, la pénalité ne représente qu'une faible part du paiement découplé.

l'objectif environnemental. Dans ce chapitre, nous montrons qu'en cas de substitution partielle des paiements découplés par le soutien aux biocarburants, il convient de changer le type de pénalité infligée aux agriculteur en cas de non-respect des standards environnementaux : la pénalité maximale n'est plus le paiement découplé, mais un paiement fixe exogène.

Partie III

Cette dernière partie propose un nouveau cadre théorique de régulation pour l'agriculture européenne, dans lequel deux niveaux de régulation (l'UE et les différents Etats Membres) contrôlent chacun un bien produit par un agriculteur. L'UE s'intéresse au bien environnemental (e.g. l'effort de réduction d'émissions polluantes), les Etats Membres possédant un secteur agricole important sont pour leur part intéressés par la production de commodités agricoles afin d'augmenter le revenu de leurs agriculteurs. Ce cadre théorique vise à formaliser le dilemme auquel est confrontée l'agriculture, qui produit des commodités agricoles en quantités importantes (du fait des prix élevés) et doit également respecter les dispositions environnementales qui ont été intégrées dans la PAC. Ainsi, la théorie de l'Agence Commune sera mobilisée pour cette partie.

La Théorie des Contrats a récemment été enrichie d'un nouveau cadre pour étudier les comportements de compétition entre deux principaux : il s'agit de la littérature "Multiprincipal-Agent" (ou de l'Agence Commune) qui a été initiée par les articles de Stole (1991) et Martimort (1992). Elle fait aujourd'hui encore l'objet d'abondants développements par ces deux auteurs (Martimort et Stole, 2003 et Martimort, 2006). Un jeu d'agence commune met en relation un agent possédant une information privée (son type), face à n principaux (en général, $n = 2$). Deux principaux proposent de manière simultanée et non-coopérative des menus de contrats. Ces contrats sont principalement des tarifications non linéaires, qui sont signés pour une seule période. Lorsque les deux activités sont des substituts dans la fonction d'utilité de l'agent (cas de l'agriculteur qui produit une culture alimentaire et une culture énergétique), le comportement non coopératif des Principaux réduit les distortions.

Enfin, le dernier chapitre s'intéresse à la régulation du secteur agricole par deux entités : un régulateur européen, contrôlant la production d'un bien environnemental par l'agriculteur et le régulateur national (l'Etat membre), intéressé pour sa part par la production d'un bien agricole "classique" et désirant augmenter les revenus de son secteur agricole. L'objectif de ce chapitre n'est pas de comparer une situation (hypothétique) dans laquelle les deux régulateurs seraient fusionnés par rapport à une situation de compétition en Nash entre les régulateurs. Le but poursuivi consiste à comparer deux situations de compétition entre les régulateurs : une compétition en Nash avec une compétition en Stackelberg, dans laquelle le régulateur environnemental est le leader. Les cas d'information parfaite et d'asymétrie d'information sont traités.

Ce cadre théorique est appliqué à la prise en compte de l'environnement dans les réformes de la PAC. Nous considérons que les réformes successives de la PAC ont abouti à un changement dans le déroulement du jeu entre le régulateur environnemental (l'UE, dont les objectifs sont alignés avec les pays ayant un secteur agricole peu important et/ou très préoccupés par la protection de l'environnement) et le régulateur national (l'Etat membre disposant d'un grand secteur agrciole) : l'UE, à la faveur notamment de la montée des préoccupations environnementales, a su s'imposer comme un leader de Stackelberg dans les négociations visant à réformer les dispositions environnementales de la PAC. La compétition entre les deux régulateurs a donc évolué d'un jeu en Nash, à un jeu en Stackelberg.

Ayant acquis cette position de leader, l'UE pourra continuer à jouer son rôle de régulateur dans la situation extrême (mais possible) d'une renationalisation de la PAC de l'après-2013 : les subventions à la production seraient alors à la charge des Etats, mais il serait nécessaire de maintenir une régulation supra-nationale pour garantir le respect des dispositions environnementales héritées des réformes de la PAC. Ainsi, ce cadre théorique peut non seulement expliquer les évolutions observées au cours des réformes passées de la PAC, mais également être utilisé pour les réformes futures de la PAC, dans lesquelles la séparation entre les deux régulateurs seraient marquées de manière très nette (renationalisation des soutiens à la production).

Les principaux résultats du chapitre sont les suivants :

- La comparaison entre le cas d'une concurrence en Nash et en Stackelberg montre que le niveau de production du bien environnemental est supérieur dans le cas "Stackelberg" par rapport au cas "Nash", les biens agricoles "classiques" étant pour leur part produits à des niveaux identiques dans les deux cas. Le changement de la structure du jeu entre les deux régulateurs aboutit ainsi à une meilleure prise en compte de l'environnement.

- La comparaison des cas "Stackelberg" en information parfaite et en information asymétrique fait apparaître un intérêt pour l'Etat membre (le suiveur) de l'existence d'une asymétrie d'information entre l'agriculteur et ses régulateurs : le bien-être de l'Etat membre est en effet supérieur dans le cas d'une asymétrie d'information, ce dernier bénéficiant de la rente informationnelle que le leader de Stackelberg (le régulateur Européen) doit consentir à l'agriculteur. Le fait de ne pas être leader dans la mise en place de la politique n'est donc pas si pénalisant pour l'Etat membre.

Conclusion

Cette thèse a cherché à mettre en avant les nombreux liens qui existent entre les politiques de promotion des biocarburants et les évolutions de la PAC. Les nombreux mérites qui ont été attribués aux biocarburants au moment des lancements des programmes depuis 2003-2004 sont aujourd'hui remis en cause. En particulier, l'externalité environnementale positive en matière d'émission de gaz à effet de serre pourrait en fait se révéler être une externalité négative. La réflexion sur le bien-fondé des biocarburants (qui n'avait pas été menée au moment des décisions de vastes programmes de biocarburants) est enfin lancée. Un moratoire sur de nombreux programmes biocarburants semble inéluctable (et souhaitable).

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Summary:

Biofuels are being extensively developed around the world thanks to the support of states, which is a necessary condition for their production. Thus, the focus of this dissertation is to study the regulation of biofuel policies. More precisely, this work intends to enlighten the strong links between biofuel and agricultural policies. Policies directed to biofuel production have changed dramatically over the past three years, evolving from the status of a secondary policy within agricultural policies to the position of a central policy at the crossroads of agricultural, environmental and energy policies. The work exposed in this dissertation is divided in three parts. First, the reasons that have led to the sudden development of biofuels are presented. Then, in a second part, the interactions of biofuel policies with the present agricultural policies are dealt with. The aim of this second part is to assess the extent to which these policies ought to be amended in order to account for the growing importance of energy crops in the total agricultural production. Finally, the third part focuses on the new regulatory framework imposed by the dual production of the agricultural sector (an environmental good and an agricultural commodity): a Common Agency setting is chosen to address this issue. Hence, the common thread of all the ideas developed in this dissertation is the mutual interactions that exist between biofuel and agricultural policies. Biofuel policies have emerged thanks to the reform of the CAP in 1992, are now an important player of the present CAP and will undoubtedly be a central issue in the future reforms of agricultural policies.

Keywords : Biofuels, Common Agricultural Policy, Welfare Economics, Contracts Theory.

Résumé:

Les biocarburants connaissent un développement rapide dans de nombreux pays grâce au soutien apporté par les Etats, qui est une condition nécessaire de leur production. Ainsi, cette thèse vise à étudier la régulation des politiques de soutien aux biocarburants. Plus précisément, ce travail a pour objectif d'éclairer les liens étroits tissés entre les politiques de biocarburants et les politiques agricoles. Les politiques de biocarburants ont évolué de manière radicale au cours des 3 dernières années, passant du statut de politique subordonnée à la politique agricole à une position centrale, à la croisée des politiques agricoles, environnementales et énergétiques. Le travail présenté dans cette thèse s'articule en trois parties. Premièrement, nous présentons les raisons qui ont présidé au développement rapide des biocarburants. Ensuite, dans une seconde partie, les interactions des politiques de biocarburants avec les politiques agricoles actuelles sont examinées. Cette seconde partie vise à évaluer les nécessaires modifications à apporter aux politiques actuelles afin de tenir compte de l'importance croissante des cultures énergétiques dans la production agricole totale. Enfin, une troisième partie s'attache à étudier un nouveau cadre théorique pour la régulation du secteur agricole, dont la production est duale (il produit à la fois un bien agricole "classique" et un bien environnemental) : la théorie de l'Agence Commune est utilisée pour cette modélisation. Ainsi, le fil conducteur des idées développées dans cette thèse est l'étude des interactions entre politiques de biocarburants et politiques agricoles. Les biocarburants sont apparus à la faveur d'une réforme de la PAC en 1992, sont maintenant des acteurs centraux de la PAC actuelle et représenteront sans conteste un aspect incontournable des futures réformes des politiques agricoles.

Mots-Clés : Biocarburants, Politique Agricole Commune, Economie Publique, Théorie des Contrats.